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ABSTRACT

This document is a teacher's edition of a basic skills curriculum in science for adult basic education (ABE) students. The course consists of 25 lessons on basic science concepts, designed to give students a good understanding of the biological and physical sciences. Suggested activities and experiments that the student can do are also included. The teacher's edition contains all of the content of the student text and an accompanying teacher's page for each lesson that states lesson objectives, ideas for discussion, and sources of additional information on the topic. The lessons cover the following topics: human senses; eye structure and function; aging, life expectancy; fever, infection, immunity; calories; cell growth; life cycles, parasites, disease; chromosomes, sex determination; bird anatomy and behavior; communication, animal behavior; speed of sound and light; characteristics of ice, freezing point of water; water facts and water cycle; friction, inclined plane; pulleys, mechanical advantage; levers; wheels and axles; siphons, barometers, air pressure; fuses, electricity; wet and dry cell, static electricity; speed, motion, momentum, and acceleration; motion, gravity; energy conservation; fire, bleach, boiling point; and evaporation. (KC)

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Teacher's Edition

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TO THE TEACHER

The purpose of these materials is to provide a basic skills curriculum in science for the ABE student (0 - 8 grade level). It was our intention to develop a science curriculum which will intertwine with the everyday life of the adult learner. We believe the most effective approach of motivating and maintaining the interest of the learner is to place the subject matter in a context which is familiar to ABE students and represents a relevant and practical base. The curriculum content will be addressed in a fashion which will cover the various roles of the adult learner, that being as a parent, citizen, consumer and worker.

We believe one of the major impetuses for developing favorable learning conditions is to demonstrate to the student that the curriculum can be of service and value to them. To that end the curriculum was designed to consist of meaningful and relevant information. We believe by taking this high interest approach that the curriculum will be exciting, motivating, and beneficial.

Specifically, the complete set of materials for *Basic Science Living Skills for Today's World* includes a student textbook, a teacher's edition and three cassette tapes. There are twenty-five lessons of basic science concepts. The student textbook is designed so they will obtain a good understanding of the biological and physical sciences. We have arranged the material so they will gain a basic understanding of the topics and then will have an opportunity to go further if they are able. There are also suggested activities and experiments that the student can do. The teacher's edition contains all of the content which is in the student text and an accompanying teacher's page for each lesson which states lesson objectives, ideas for discussion and sources of additional information on the topic. The cassette tapes are an audio version of the content of the student textbook. This is naturally optional but may prove very helpful for the student who is having difficulty reading the materials.

We have tried to present a basic skills science curriculum in an interesting, comprehensive and contemporary manner, and we hope you will find these materials of value to your program.

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Biological Science: Lesson 1

This Makes Sense

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that humans have five major senses.

√ emphasize the importance of all five senses.

√ explain how each of the different senses functions.

For Class Discussion:

√ How would you rank the relative importance of each of the five senses? Explain the reasons for your ranking.

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979.
(pages 79-101)

Biological Science: Lesson 1

This Makes Sense

Science Concept:

Human Senses

It is generally agreed that humans have five major senses. These include feeling, seeing, hearing, smelling, and tasting. Sometimes people claim to have a sixth sense. Since this goes beyond the five "normal" senses, the sixth sense is called extra sensory perception. This is more commonly known as ESP. Sometimes a form of the sixth sense is referred to as a "woman's intuition" or as a "mother's intuition." It should be noted that not all people believe in a sixth sense.

All of the human senses are important to our total well-being. It would be difficult to select the one that is *the* most important. In some cases it is the individual's situation that determines which sense is the most important to him/her. For example, a band director's sense of hearing would probably be more important than his/her sense of taste or smell. But to a gourmet chief, his/her sense of taste might be more important than his/her sense of hearing.

Let us consider another example. Consider an elderly composer of music who is confined to bed due to poor health and old age. This person may indicate that listening to music gives more pleasure than viewing things. In this special case, the sense of hearing might be considered to be more important than the sense of sight.

The importance of a given sense can change depending on the situation. When you are in a photographer's darkroom, you will probably place limited value on the sense of sight. In this situation the sense of touch becomes very important. Later, when you are watching a movie on TV, your sense of sight becomes very important. Your sense of touch becomes much less important.

Let us examine how each of these senses operate. But since there is so much to say about the sense of sight, it will be discussed separately in lesson two.

The Sense of Hearing

The ear is a very complex organ. It has two major areas; an outer part and an inner part. The outside ear is separated from the inside ear by a thin membrane called the eardrum. It is the eardrum that prevents objects such as water and mosquitoes from going into our head. The inside ear has several structures that allow us to hear sounds. The inside ear leads to the throat.

Before you can understand how an ear works, you must know something about sound. Sound is nothing more than the vibration of molecules. When you clap your hands together, you force millions of air molecules to vibrate. When you hit or tap a glass with a fork, you cause the glass and fork molecules to vibrate. This causes the air molecules to vibrate. These vibrations can travel through the air by causing adjacent moelecules to vibrate. This is known as a sound wave. The speed of the vibrations determines the pitch of the sound. The strength of the vibration determines the loudness of the sound.

The way an ear works is very interesting. The purpose of the outside part of the ear is to collect sound waves. These waves travel to the eardrum. When a sound wave hits the eardrum, the eardrum begins to vibrate. This vibration is in the same pattern as the vibrations that caused the original sound. The vibration of the eardrum causes some very small bones in the middle part (inside) of the ear to vibrate (move). This in turn causes a fluid within the ear to move. This moving fluid stimulates nerve endings in the ear. Impulses travel through the nerve to the brain. The cerebrum of the brain then recognizes this as sound.

The pressure on both sides of the eardrum is usually the same. This is because air can come from the throat to push on the inside of the eardrum. When you go up or down a tall hill or mountain, the outside air pressure changes. The pressure inside your throat may not change as quickly. You will now have one pressure on the inside of the eardrum and a different pressure on the outside. If this pressure difference is large, your eardrum can begin to feel uncomfortable. This is when you usually try to "pop" or "crack" your ears. When your ears "pop," this is simply the pressure on each side of the eardrum becoming equal again. Chewing gum, swallowing, or yawning are ways to help your ears to "pop."

When you get a cold, fluids can build up inside the ear. This can reduce your ability to hear. It can also make it difficult for your eardrum to "pop." Sometimes the pressure from the fluids in the ear actually break the eardrum. For most people this is very painful.

Sometimes people have continuing problems with fluids in the ear. This is not uncommon in some children. To help maintain a balanced pressure, the doctor can put a tube through the eardrum. This allows the air pressure to be the same on both sides of the drum. You can still hear very well when you have a tube in your eardrum. After several months the tube will fall out, or the doctor can take it out. By then, it is hoped that the extra fluid in the ear has drained.

Besides helping you to hear, your ear has another function. It helps you to balance your body. Inside the ear there are three sets of tiny canals that are near each other. These are called semicircular canals. Inside these canals there are many nerve endings and some fluid. When the head changes position, the fluid touches different nerves. From this, our brain can determine the position of our head. With the help of our eyes and other senses, we then know the position of our body.

If you spin around rapidly, all of the fluid in the semicircular canals rushes to one part of the canal. When you stop spinning, the fluid flows back across the nerves giving you the sensation of going the other way. You are now dizzy. You can reduce the sensation of dizziness when you spin. This is done by moving your head in quick, jerky movements. (Inertia will tend to keep the fluid from moving.) Professional dancers and ice skaters who spin their body use this method to reduce the feeling of being dizzy.

Diseases that attack the semicircular canals can result in temporary or permanent dizziness. Motion sickness is also associated with the movement of the fluid in the semicircular canals. Many people react negatively to regular, rhythmic motions such as ocean waves.

The Sense of Taste

Foods and other materials are made from chemicals. These chemicals are made from molecules. There are many different kinds of molecules. On your tongue you have structures called taste buds. Taste buds contain nerve endings that can tell one type of molecule from another.

When we put food into our mouth, the food mixes with saliva. When this mixture touches a taste bud, a nerve ending is stimulated. A message goes to the brain. The brain then recognizes the taste of the molecules on the taste buds. We can only recognize four common flavors. These flavors include sour, sweet, salty and bitter. Hence, all of our tastes are some combination of these four flavors. A taste bud is specific for one of those four flavors. Furthermore, our taste buds are not evenly distributed on our tongue. Those that are sensitive to sweets tend to be at the tip of the tongue. Salty flavors are also best tasted at the tip of the tongue. You taste sour flavors from the taste buds along the sides of the tongue. Bitter flavors are detected at the back of the tongue.

This explains why candy tastes sweeter when you lick it with the tip of your tongue than when you chew it at the back of your mouth. Maybe this is why we tend to lick ice cream cones. This also helps us to understand why sweet and salty flavors tend to be noticed faster than bitter flavors. Also, some foods do not have any of the four flavors that we can taste. For example, hot peppers have no distinct flavor. The chemicals in the peppers irritate all of the taste buds and we notice a burning sensation.

It may come as a surprise to you that much of what you think you are tasting is really a smell. This is why your sense of taste appears to be reduced when you have a head cold. In reality, it is your sense of smell that has been reduced.

The Sense of Smell

Your nose is the location for the nerves that can detect smell. The nasal passages contain tiny branches of a special nerve. This nerve is called the olfactory nerve. Stimulation of these nerve endings results in the sensation of smell. This stimulation is done with molecules that are in the air. The process of smelling things is similar to the process of tasting things. One difference is that you taste things in the liquid form (saliva mixed with food), but you smell things by the vapors that they produce. When you smell something, you are actually breathing molecules that have been given off by that substance. This is not a very pleasant thought to have when you smell odors from a sewer.

It is possible for an olfactory nerve ending to become temporarily deadened to a certain odor. This can happen if the nerve ending is exposed to a certain odor for a long period of time. This temporary deadening can be a blessing if you should ever have the misfortune of being sprayed by a skunk. This also explains why people coming into your house can smell things that you do not smell. In other words, you can get used to a certain smell.

The Sense of Touch

Our skin is the location of the nerve endings that detect touch and other sensations. These nerve endings are called receptors. Humans have five different types of receptors. Each type can detect a different sensation. We can detect pain, pressure, heat, cold and touch. These receptors are scattered unevenly over the skin area of our body. Some receptors, such as those for touch, are close to the surface of the skin. The tip of the tongue, the fingertips and the forehead are three places that have a high number of touch receptors. Others receptors, such as those for pressure, are deeper in the skin. Pain receptors can respond to a variety of stimuli. For example, you can stimulate a pain receptor with chemicals, electricity, heat and by mechanical means. The fact that you can detect pain allows you to take the necessary action to stop the cause of the pain. This has survival value to you. People who have nerve damage and cannot feel pain must be especially careful not to injure themselves. For example, if you place your hand on a hot stove, you quickly feel pain and move your hand. But if a person does not feel that pain, the injury could be extremely serious.

A Little Bit More

It is interesting to note that hot and cold stimulate different receptors. This is very important because cold is nothing more than the absence of heat. In other words, hot and cold are extremes of the same thing. That is, they are both a measure of the amount of heat present. For humans, too much heat is dangerous and so is too little heat. If both heat and cold stimulated the same type of receptor, we could tell that there was a problem. But we could not tell whether the problem was too much or too little heat. Hence, we could not take the necessary action to correct the problem. The design of the human body is truly amazing.

Something to Try

The purpose of this activity is to test the influence of smell on ones ability to taste. You will need to work in pairs or small groups. First, locate several different types of foods to which nobody in the group is allergic. Many of these foods should be similar in their consistency (This will prevent the people from identifying the food based on its consistency.) For example onions, apples and potatoes would be similar.

Next, blindfold someone in the group and ask them to hold his/her nose. He/she should then chew and try to identify small amounts of the different foods. Keep track of the success. You should then keep the blindfold on, but allow the person to retaste the foods without holding his/her nose. If the experiment is properly conducted, most people will score worse when their nose is not available to assist them in the identification of the food.

Something Else to Try

Find some foods that are sweet, sour, bitter and salty. Try placing small amounts of these foods on different locations of your tongue. Can you verify that salty and sweet foods are best tasted at the tip of the tongue? Did you find that sour foods are best tasted along the sides of the tongue? Finally, were the bitter foods more flavorful at the back of the tongue?

Biological Science: Lesson 2

I See You

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that the eye is a delicate and complex organ.

√ emphasize the need to protect the eye.

√ explain the function of selected parts of the eye and relate them to a camera.

For Class Discussion:

√ Who do you think is at greater disadvantage, a person who is nearsighted or a person who is farsighted? Would your answer be the same if you were living in the days of cavepeople? Explain.

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 83-84)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 270-271)

Biological Science: Lesson 2

I See You

Science Concepts:

Eye Structure

Eye Function

As we discussed in lesson 1, all of our senses are important. However, most people would rank the sense of sight above the sense of taste, touch and smell. You have probably heard someone say something like, "Don't let it hit you in the eye." Or maybe your boss has told you to wear your protective eye goggles when doing a certain job. These types of warnings show how careful we are with our eyes. On the other hand, when is the last time that you had someone tell you to protect your sense of smell? Has anyone ever told you to cover your touch receptors before doing a dangerous job?

Eye Structure

Figure 2.1 is a sketch of how a typical eye appears. Only some of the eye's parts are shown in this sketch. As you can see, the structure of the eye is spherical. This means that it is similar to the shape of a baseball. Most eyes have a small bulge in the front. This is the cornea. The cornea is part of the outer layer of the eye. The cornea is the white part of the eye that you can easily see when you look at someone's eye. This is the part of the eye that sometimes gets scratched when you get dirt or other material into your eye.

The small opening behind the cornea is called the pupil. Light passes through this opening. Around the pupil is the iris. The iris is the blue, brown, green or hazel portion of the eye. Muscles in the iris allow it to move. When it moves, the pupil gets smaller or larger. This is the main way that your eye has to control the amount of light that enters. When you are in a bright room, the pupil becomes small. This keeps out some of the bright light. When the pupil is small we say that it is constricted. If some of the lights were to be turned off, the pupil would immediately get larger. When the pupil is large, we say that it is dilated. You do not control this action by the iris. It is automatic.

When you go to the eye doctor, he/she sometimes puts liquid drops into your eye to cause the pupil to dilate. The drops cause the muscles in the iris to make the pupil large. The doctor does this so that he/she can use a small, bright light to look into your eye. By looking into your eye, the doctor can actually look at your blood vessels. This is the only place in your

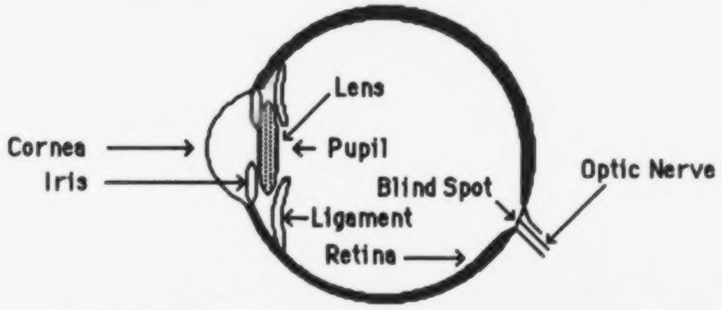


Figure 2.1 Structure of the human eye

entire body that doctors can see blood vessels without doing anything "special." (You do not actually need the drops to look into the eye. But using drops makes the doctor's job easier.) When you get drops in your eyes the doctor may give you a pair of dark glasses to wear. This is to help keep the "extra" light out of your eyes until the effect of the drops wears off.

There is a lens behind the iris and the pupil. The lens is flexible, and its shape can be changed by muscles that are connected to it. Changing the shape of the lens allows the image to be focused on the retina. Many of the common problems that people have with their eyes relate to the lens. As we will learn later, it is the shape of the lens that causes people to be nearsighted or farsighted.

The inner layer of the eye is very complicated. It is called the retina. The retina is very thin and delicate. Even so, it has several layers of cells and fibers. Many of the cells of the retina have a very special function. For example, two of the cell types are designed to sense light. They are called rods and cones. Rods and cones are connected to small nerves which in turn are connected to the optic nerve. The optic nerve comes from the brain and enters the back of the eye. At the point where the optic nerve enters the eye, there are no rods or cones. Hence, that small place on the retina cannot sense any light. We call that place the "blind spot."

Eye Function

When light hits an object, the light is reflected. The reflected light contains information about the color, size and shape of the object from which it was reflected. When this reflected light enters the eye, it will cause a series of things to occur. The end result is that our brain interprets the image of the object that reflected the light. We call this the process of seeing. There are many details related to the process of seeing. The following is a summary of some things related to this process.

The rod and cone cells of the retina play an important role in the process of seeing. The cones are able to distinguish colors, the rods are not. In addition, cones are sensitive only to bright light. So during periods of reduced light, the cones are not activated. Only the rod cells are activated in low light situations. But since the rod cells cannot distinguish colors, no color vision can take place in reduced light.

One reason that rod cells can function in dim light is because they can produce a chemical called visual purple. Rod cells can only work in reduced light when there is visual purple present. When your rod cells are able to produce lots of visual purple, you can have good "night vision." Vitamin A is essential to this process.

It is interesting to note that visual purple fades when it is exposed to bright light. When this happens, the rods do not function well, and you will temporarily become "night blind." As soon as the bright light is removed, the visual purple begins to return. As the visual purple returns, so does you night vision. However, it takes several minutes to fully restore the visual purple to its original level.

This has very important implications for people who drive at night. Assume that you are driving on the highway during a period of dim light. There is a lot of visual purple present in your eye. The rod cells are doing their job. You can see just fine. Then all at once some thoughtless driver coming toward you flicks on his/her high beams. What does that do to your night vision? It reduces it because the bright headlights fades the visual purple in your eye. You now may have trouble seeing important details such as road signs or the white line down the center of the road. Will it help the situation to immediately flick on your high beams? Probably not. The damage to your visual purple has already been done. Although flipping on your high beams may slightly increase your ability to see, you will then have someone driving toward you who is also night blind.

What is the solution to the above problem? Prevention. Dim your headlights when you see another car coming toward you. Encourage others to do the same. Be sure that your lights are properly adjusted. This will protect the visual purple of the other driver. It will also reduce the chance of him/her thinking that you have your high beams turned on. Do not look directly into the headlights of an on-coming car.

Within limits, the human eye can change the focus of the image being sent to the retina. This is done by muscles that change the shape of the lens. However, for some people the image is too far out of focus to be corrected by the muscles of the eye. When this occurs, people can wear glasses or contacts to help focus the image on the retina.

There are two common types of problems associated with an inability of the eye to focus properly. People with these problems are either nearsighted or farsighted. Nearsighted people have blurred vision because the image focuses in front of the retina, as shown in Figure 2.2. The only time that nearsighted people have clear vision, is when the object being viewed is very close to the eye. Hence the term nearsighted. By adding the correct shape

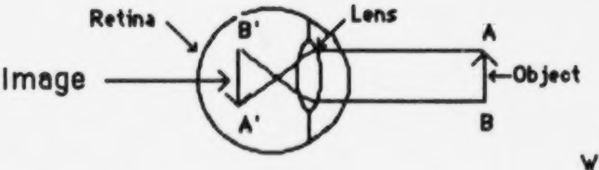


Figure 2.2 Nearsighted eye

of lens in front of the eye, nearsightedness can be corrected, as shown in Figure 2.3. Nearsightedness results from an eyeball that is too long or from a lens that is too convex (curved).

Farsighted people have just the opposite problem. Their eyeball is either too short or their lens is too flat. The focus point of their image would be behind the retina. Hence, the image that strikes the retina is blurred. Farsighted people have sharp vision only for objects that are far away. The addition of a correctly shaped lens in front of the eye can help to focus the image clearly on the retina.

Another common problem is called astigmatism. This is when a person's cornea or lens is somewhat irregularly shaped. This results in parts of the image being out of focus. This situation can be corrected by the use of glasses which counteract the irregularities.

A Little Bit More

In many ways an eye and a camera can be compared. The light-sensitive film could be compared to the retina. This is where the image is received. Both a camera and an eye have a lens to help focus the image. In both cases the image will be smaller than the real object being viewed. In addition the image will be inverted. The diaphragm of the camera regulates the amount of light that can enter. The eye's iris also does this. Light can be kept out by the camera's shutter. The eyelids of an eye do a similar task.

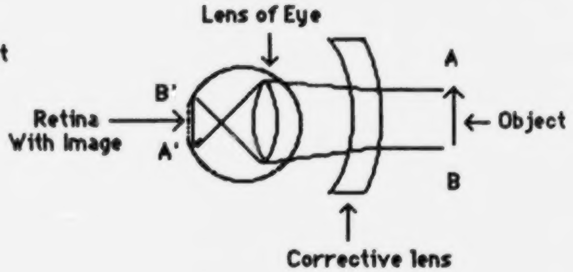


Figure 2.3 Correction for nearsighted eye

Do you think that these similarities are by chance? There is a belief held by many people that an object's form follows its function. This means that the design of an object depends on what it is to do. Since the eye and the camera do similar things, it should not be surprising that they have similar parts. This concept can also be seen by comparing a bird and an airplane. Can you think of other such pairs of objects?

You are probably aware that cats, owls and some other animals have excellent night vision compared to humans. This is because they have more rod cell in their eye. It is interesting to note that the owl lacks cone cells. It is "day blind."

One last bit of information. The eye is protected in several ways. First, it is built back into the head. Thus the bones of the nose and eye socket help to protect it from mechanical injury. Also, the eyelids close automatically when something comes toward the eye. In addition, the outer layer of the eye has many nerve endings that sense the presence of pain. This allows us to take appropriate action to protect the eye. Finally, tears wash the eye and keep it clean. Did you know that tears contain a chemical that kills certain forms of bacteria? This is yet another protective device for your wonderful organ, the eye.

Something to Try

This activity will demonstrate how a "flash" of bright light can reduce your night vision.

Find a room or other space that is *almost* dark. A closet with a very small crack under the door should be just about right. After being in relatively bright light, enter the dark closet. Notice how much you can see. It would probably be more accurate to notice what you *can't* see. Wait patiently for several minutes. Notice that you can slowly begin to see things that were not visible just a few minutes earlier. (This is because your visual purple is beginning to build up. This allows your rod cells to function in reduced light.) Can you see colors? If you can, the room is too bright to do this activity.

After being in the dark room for several minutes, close one eye. It may even help to also cover it with your hand. Now go back into the bright light for several seconds. Do **not** open the closed eye. Do not even peek with it. Go back into the dark closet. What do you see with the open eye? Probably very little or nothing. Now open the eye that has been closed. What do you see? Probably a lot more than with the eye that was exposed to the bright light. Why is this true? The eye that was not exposed to the bright light retained its visual purple. The other eye did not. Hence, the rod cells in the closed eye could continue to function.

How long does it take for your night vision to become equal in both eyes? You can determine that by staying in the closet and continuing to test and compare the two eyes.

Something Else to Try

This activity will allow you to observe the change in size of the eye's pupil in response to a change in lighting conditions.

Although you could use a mirror, this activity works best when you have a partner. Turn on as many room lights as possible. Observe the size of your partner's pupil. Have someone turn off most (or all) of the lights. Wait a second or two and turn them back on again. Did you notice that the pupil changed size? If it did not, ask your partner to move closer to the light and try again. You should be able to observe the pupil change size, as the lights go on and off. When the light is on, the pupil should be smaller than when the light is off. This is how your eye controls the amount of light that enters your eye. What happens if the pupil is closed as far as it can go (It does **not** close all the way.), and the room is still too bright? Then you will probably squint to keep out the extra light. This is frequently necessary on bright, sunny days when there is snow on the ground. Do you know why the snow makes a difference? It is because the snow reflects most of the light that hits it. Dirt absorbs much of the light that strikes it. Hence, snowy days are brighter. Similar conditions can develop at the beach where there is a lot of sand and water. Both sand and water reflect much of the light that strikes them. Wearing polarized sun glasses can help to reduce the amount of light and glare that reaches the eye.

Biological Science: Lesson 3

Are You Becomming Old?

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept that aging is a natural process, but one that can be tempered by modern medicine, good nutrition *etc.*
- √ emphasize the continuing increase in life expectancy.
- √ explain how life expecytancy data can be influenced by infant deaths.

For Class Discussion:

- √ Why do you think women tend to live longer than men?

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 143-161)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 300-329)

Biological Science: Lesson 3

Are You Becomming Old?

Science Concept:

Aging
Life Expectancy

Have you ever heard of the "Fountain of Youth?" Some early explorers looked for a fountain whose water would keep people young. Of course no such water has ever been found. The dream of being young forever is still just a dream.

All living things must age. The concept of aging is a subject of much study. Nobody knows for sure why we age. Some believe that aging is the breakdown of our immune system. Others believe that aging is the result of a "genetic program" that we inherit from our parents. There are still many questions about aging. But we do know several things relating to this topic. Lets consider some of these things now.

For example, we know that the idea of "old" has changed through time. In ancient Greece the average life expectancy was about 18 years! For ancient Rome the average age of death was about 23 years. In 1790 the average American only lived about 33 years. Today we can expect to live for about 73 years.

In Figure 3.1 we can see how the average American's length of life has increased. What has caused this large increase in length of life? Is the human species getting better? Probably not. Most of the increase in length of life is due to a better standard of living. We have better medical care. We have improved our diet. There are fewer infant deaths. We take better care of ourselves. We have child labor laws to protect children. All of these factors help to increase the average length of our lives.

Can this increase continue forever? Probably not. But nobody knows for sure where it will level off. Many people believe in the idea of a maximum age for a given species. Mayflies live their entire adult life in one day. The oldest cat lived about 28 years. The Bible says that Methuselah lived to be 969 years old. But that is a special case. One scientist believes that the length of an animal's life is related to its body size. Big animals outlive small animals. But humans already live almost three times longer than "expected" according to his formula.

Did you realize that plants also have a life span? Several plants have a life span of only one growing season. But other plants live a long time. The White Pine

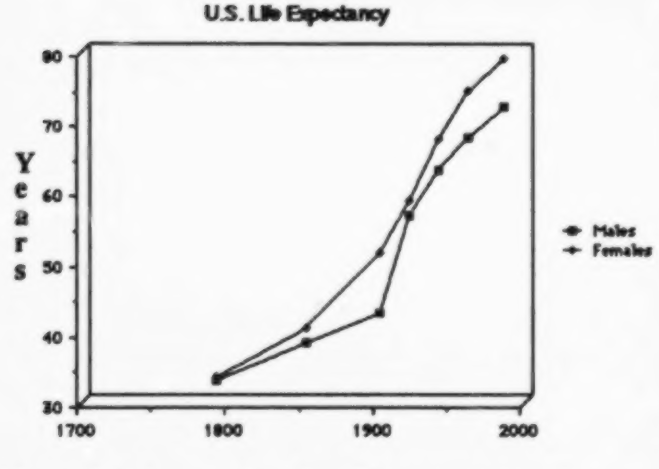


Figure 3.1 Average American life expetancy

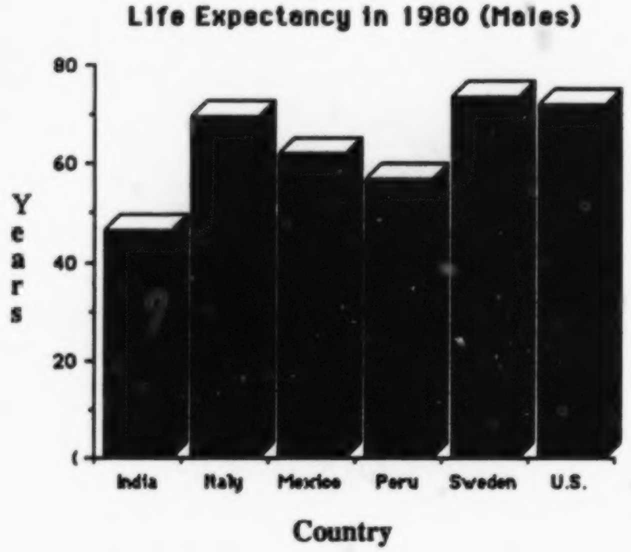


Figure 3.2 Male life expectancies in selected countries

lives for almost 500 years. One of the longest lived trees is the Bristlecone Pine. It lives almost 5,000 years!

It is important to note that age alone is not a good way to tell if a person is "old." Many people who are 80 years old feel young. These people can be very useful. Because of illness or other reasons, some "young" people feel old. There is a saying that states, "You are only as old as you feel." Are you old?

Something to Try

Go to a cemetery and look for old gravestones. Take the first dozen or so that you find with a birthdate before 1850. For each marker, figure the age at which the person died. To do this you should subtract the birthdate from the date of death. Next, calculate the *average* age at death. Do this by first adding up the ages of all the people. Then divide this answer by the number of people.

Repeat the above process. But this time only use data for people who were born after 1900.

Compare the two averages with each other. It is expected that the second group will have a higher average.

Compare your averages to Figure 3.1. Are your numbers similar to those in the table? If not, you should be able to think of several reasons why they are not.

Biological Science: Lesson 4

Here Come the Germs

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that disease is caused by bacteria, viruses and other microscopic organisms.

√ emphasize that good health habits can reduce the chance of disease.

√ explain the many different ways that germs can enter our body.

For Class Discussion:

√ How can plastic garbage bags help to reduce disease?

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 143-161)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 300-329)

Biological Science: Lesson 4

Here Come the Germs

Science Concepts:

Fever
Infection
Immunity

At one time or another, almost everyone has asked the question, "Why do I get a fever?" A higher than normal body temperature (fever) usually comes when you are sick. It is one way that your body has to fight germs. The higher temperature slows down the growth of the germs that are in your body. A fever will help you fight germs, and that is good.

If a fever is good, why do we take medicine to lower the fever? Many people try to lower a fever for at least three reasons. First, if a fever gets too high or lasts too long, it can damage your body. Second, sometimes you feel better with a lower fever. Third, not all fevers are the result of germs. You can get a fever from things like sunstroke. This fever is very dangerous and should be reduced. The only sure way to know whether or not you should try to lower your temperature is to ask your doctor.

Besides causing a fever, there are a lot of other useful things to learn about germs. For example, not all germs are the same. When you are sick and visit a doctor, the doctor may say that you have a virus or a bacteria. These two types of germs are different. They cause different types of illness. They must be treated differently.

Germs can enter our body in many ways. Sometimes these germs are in the food that we eat. Some germs are in the water that we drink. This is one reason why it is important for the cook to always have clean hands. The dishes and silverware must always be clean so that germs cannot be spread from one person to another. Examples of diseases that can come from dirty food and water include typhoid fever and dysentery.

After a flood, people are sometimes told to boil the water. This is to kill the germs that may have washed into the water system due to the flood. Normally, germs in the water supply system are killed with chemicals such as chlorine. But during a flood the system may not function properly.

Illness can also occur by breathing air that has harmful germs. Germs such as bacteria and viruses are very small. You cannot see them without a microscope. They are so small, they can "float" through the air. In some cases they get into the air from a sneeze. Examples of illness that we can catch by breathing the germs include the flu, measles, and the common cold. To reduce the number of germs in the air people should sneeze and cough into a tissue or handkerchief.

You can also get certain illnesses by direct contact. If you shake hands with someone that has germs on his or her hand, you could get those germs on *your* hand. Then if you rub your eye, touch your nose, or put your finger into your mouth, that germ could enter your body. Impetigo is an example of a disease that you can get in this manner. To help your body stay healthy, you should wash you hands often. Also, you should try not to touch your eye, nose or mouth with dirty hands.

Another form of direct contact is to touch a sore on the skin of an infected person. This is the way many sexual diseases are passed from one person to another. Examples of these diseases include herpes, syphilis and gonorhea. Sometimes these types of infections are called, "social diseases." You can reduce your chance of getting one of these infections by using a condom during sexual intercourse.

Another way to get a germ is through insects. Flies, ants and roaches can carry germs on their feet. When they walk or land on your food, those germs can stick to the food. When you eat that food, you will also eat those germs left by the insect. Almost any germ can be spread in this manner. You can help to stay healthy by keeping insects away from your food. It also helps to keep garbage and other waste material in a container that insects cannot get into. This will help to starve them. It will also help keep the garbage germs from getting on the insects' feet.

Insects can also carry germs inside of their bodies. When they bite you, the germ enters your body. For example, Rocky Mountain Spotted Fever can come from the bite of a tick. Malaria is passed from one person to another by a mosquito. When in "high risk areas" you should wear clothing that will protect you from these insects.

A Little Bit More

There are so many different ways to get sick, it seems that we should always be ill. But that is not the case. In fact, many people are almost never sick. How can that be possible?

The reason that we are not always sick is because our body has many ways to protect us. One of the best protections that we have is the skin. The entire outside of our body is covered with skin. We even have "skin"on the inside of our body. The mouth, digestive tract, respiratory tract, and genital tract are lined with membranes that protect us from certain germs. If our skin is not cut or otherwise broken, bacteria cannot easily invade us. Very strong acids in the stomach destroy most of the bacteria that we eat. Even our eyes have a chemical in the tears that helps to kill certain germs.

Even after a germ enters our body, we have ways to fight it. For example, we have special cells in our blood that can find and surround germs. The germs are then killed or eliminated. Our body can also increase its temperature. This fever will kill some germs.

A third way to fight germs is with antibodies. Our body can make antibodies that react against specific bacteria and destroy them. Most people have some natural or acquired immunity to disease. A baby is often born with natural immunity to certain germs. He/she is then protected from diseases caused by these germs. This form of immunity comes to the baby from the mother. This form of defense usually "wears out" after several months.

It is also possible to *acquire* immunity to some forms of disease. Throughout your life you will continually acquire this type of immunity. You can acquire an immunity by being sick. While your are ill your body will make antibodies that destroy the germs that are making you sick. After you recover from this illness, you will still have the antibody for the germ that causes that disease. The next time that a germ of that type enters your body, it will be destroyed by the antibodies in your blood. These antibodies usually last for the rest of your life. This tells us why you only get some illnesses once in your lifetime. Mumps, chickenpox, polio and German measles are all examples of diseases that we usually get only once in a lifetime.

You can also get an immunity by being injected with a dead or weak form of a specific germ. This process is called vaccination. When you are vaccinated against a disease, you actually get a very mild case of that disease. Your body will produce antibodies against that germ. When a "full strength" form of that germ enters your body, the antibodies will destroy it. Most vaccinations last years, but sometimes a booster shot is necessary.

You should note that a vaccination will not cure a disease. It is used *before* you get sick. It is used to keep you from getting the disease.

If you are already sick, the doctor can give you a serum. The serum will contain antibodies against the germs causing your illness. (The antibodies were made in another person or in an animal.) These antibodies usually last from a few weeks to several months.

With the exception of serum, all of the previously mentioned forms of defense rely on the person's body. Modern medicine can also help you to stay well. For example, you can be given antibiotics that will kill bacteria. The antibiotics are made by living organisms such as mold. Penicillin is an example of an antibiotic. Antibiotics should not be confused with antibodies.

You can also be given chemotherapy. This process uses different chemicals to kill germs. Sulfa drugs are an example of chemotherapy. A concern for chemotherapy is that is can be dangerous. Also, chemotherapy is not a cure-all. It should be used only when recommended by a physician.

Something to Try

If someone asked you, "What is a person's normal body temperature?", what would you say? Most people would say 98.6 degrees Fahrenheit. Is this a magic number for everyone? No. In fact, your body temperature can change during the day. It can also change during the month. The number, "98.6," is just an average.

You can be healthy and still have a temperature of 99.1 or 98.2 degrees.

To see if your temperature varies you will need an oral thermometer. Make a graph like the one shown in Figure 4.1. Across the bottom of the graph you will show the hours of the day. Down the side of the graph you will show temperatures.

For at least three days, take your temperature at least every six hours. More often would be even better. Be sure to read the temperature to the nearest tenth of a degree. For example, you would read 98.4, not just 98. Plot your temperature every time that you take it. (You should be healthy during the time when you do this experiment.)

After a few days you may begin to see a daily cycle for your temperature. Some people may notice that their temperature is lowest in the early morning and highest in the evening. Compare your findings with others. Is your average temperature about 98.6?

If you are really interested in this information, keep your experiment going for a full month or more. Can you find any signs of a monthly temperature cycle? Some people probably will.

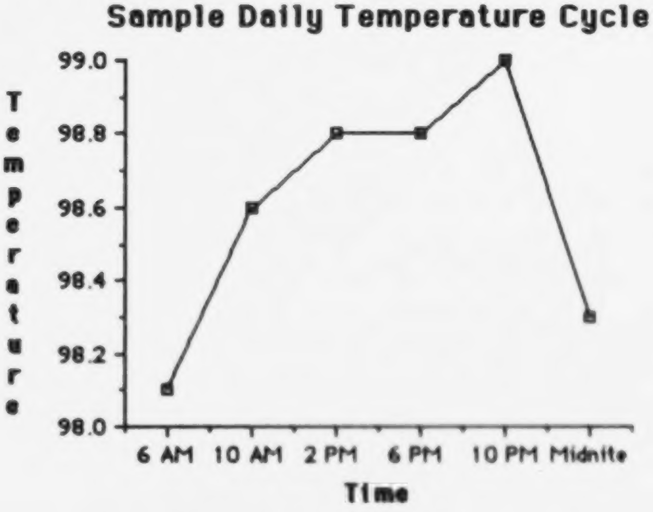


Figure 4.1 Daily temperature cycle

Biological Science: Lesson 5

Thin is In

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that weight gain and loss are dependent upon the number of calories consumed, metabolic rate and level of exercise.

√ emphasize that many "fad" diets are not healthy.

√ explain the relationship between energy and calories.

For Class Discussion:

√ Would you gain more weight by eating a pound of fatty meat or a pound of lean meat? Remember, in both cases you will eat one pound of the food.

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 125-141)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 396-403)

Biological Science: Lesson 5

Thin is In

Science Concept:

Calories

There is a cartoon character named Fat Albert. He must stay fat. If he loses weight he couldn't be Fat Albert anymore. That would not be good because nobody ever heard of Skinny Albert.

But most overweight people do not want to be like Fat Albert. Losing weight seems to be a goal for many adults in the United States. We read about diets in magazines. We read about diets in the newspaper. We see ads for diet plans. You can go to diet camps and diet clinics. There are even diet clubs. Information about diets seems to be easy to find. But even with all of this information, it is not easy to lose weight. And if we do lose a few pounds, it is hard to keep that weight from coming back. Why is weight loss such a problem? Lets look at some of the problems.

In most cases weight gain occurs when a person eats more food than his/her body needs. Food is often measured in calories. (A calorie is a unit of heat energy.) Each food can be given a calorie value. For instance, a raw apple has about 70 calories of energy. A four ounce piece of chicken contains about 200 calories. A piece of peach pie will be 300 calories.

If the calories you eat are greater than the calories used by your body, weight gain will occur. If the calories eaten are less than the calories used, weight loss will occur. The extra calories eaten each day are stored as body fat. This new fat is the weight that you gain. To lose that weight you must either exercise more or eat less.

To loose one pound of weight you must eat 3,500 fewer calories than your body needs. This is a difficult task, and it must be done slowly. One way to loose a pound each week is to eat 500 fewer calories each day for seven days. (Seven times 500 equals 3,500.) Another way to loose a pound each week is to exercise enough to use 500 calories of energy each day for a week.

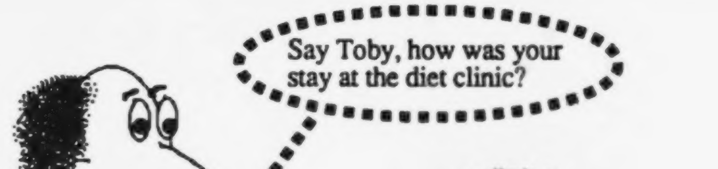
You may not want to gain or loose any weight. Maybe you want to maintain your present weight. How many calories will that take each day? That depends on several things. But you can estimate this number by multiplying your weight by 10. Then multiply that answer by 1.3 if you don't exercise regularly; by 1.5 if you are moderately active; or by 2 if you are very active.

As an example, lets say that a very active woman who weights 125 pounds wants to stay at that weight. About how many calories would she need each day? First, multiply 125 by 10 to get 1,250. Since she is very active, multiply 1,250 times 2. This answer is 2,500 calories. This is about the number of calories that she would need to keep her weight at 125 pounds.

Eating fewer calories is a good way to lose weight. But remember that you should never eat less than 1,200 calories each day. If you eat less than 1,200 calories during a day, it would be difficult to get enough vitamins, protein, and minerals. Also, if you eat less than 1,200 calories each day, your body will think that you are starving. Your body will become more energy efficient. This will save calories and make it even more difficult to loose weight.

A good diet plan is also one that keeps your body healthy. For good health, a diet should always include these foods each day:

2 cups of low-fat milk
5-6 ounces of lean meat, fish, or


Say Toby, how was your stay at the diet clinic?

poultry
2 cups of fruits and vegetables
4 servings of whole grain or
enriched breads and cereals

Things such as potato chips, desserts, fried foods, sweetened soft drinks, and alcohol should be avoided.

Exercising every day is a very good way to burn extra calories. If you walk each day for thirty minutes, you will burn about 75 calories. Jogging, basketball and other such activities will use even more calories. Over a period of time the burning of these calories will help you loose weight. (See Table 5.2)

An important point to remember is that exercise should be started very gradually and only after a doctor's examination and permission.

Beyond the Basics

A food calorie is a unit of heat energy. One food calorie is the amount of heat needed to raise the temperature of one kilogram of water one centigrade degree. A food calorie is equal to 1,000 "small" calories used by the physical scientist.

A food calorie is a lot of energy. For example, a piece of apple pie has about 275 food calories. This is about the same amount of energy as in one pound of coal or one-sixth cup of gasoline!

The caloric value of a food is found by burning a dry sample of the food. The weight of the sample must be exactly measured. The food is burned in a special container that is well insulated. All of the energy given off by the burning food goes to heat some pure water. The amount of water is exactly known, as is its temperature. The increase in the temperature of the water is measured. This increase is multiplied by the weight of the heated water.

For example, if burning a nut caused 50 grams of water to rise 20 degrees Celsius, there would have been 1,000 "small" calories of energy in that nut. (50 grams times 20 degrees equals 1,000 calories) This would be equal to 1 food calorie.

When you see calories listed in diet books, they are usually taking about "large" calories. Another name for a large calorie is a food calorie. These food calories are 1,000 times larger than the "small" calories used by most physical scientists. But both are a measure of heat energy. Too much of this heat energy causes you to gain weight.

Something to Try

It would be interesting to see how many calories that you eat each day. To do this you must find a booklet that lists the caloric value of foods. You can usually find one of these booklets in a grocery or drugs store. Some of these books only cost about $1.00. If you go to your library to find this information, it would not cost you anything.

Once you have information about the number of calories in various foods, you should make a chart like the one in Table 5.1. The values in that chart are just samples. Your values will depend on the food that you eat.

To be more accurate you should collect your data for seven days. You should weigh yourself at the beginning of the first day. Weigh yourself at the end of the seventh day.

At the end of the week, you should notice whether you gained, lost, or stayed the same weight. Then compare this result to what you would "expect to find."

By using information from earlier in this lesson, we can calculate what we would expect to find.

We already know how to calculate the number of calories needed for us to stay at the same weight. (Page two of this lesson says to multiply your weight by 10. Then multiply that answer by 1.3 if you do not exercise regularly, etc.)

For example, Table 5.1 shows a beginning weight of 206 pounds. That person does not exercise regularly. We would expect that person to need about 2,678 calories per day to keep his weight constant (206 times 10 times 1.3).

From the chart we can see that he ate 2,682 calories. This is very close to the number that he needed to stay the same weight. The person had an end weight of 206 pounds. He did not gain. He did not lose. This is what we expected.

Your actual results may not match your expected results. This is okay. Remember, our "expected results" are just a guess. To be more accurate we would have to measure your exact level of activity and know your metabolic rate.

Beginning Wt: 206 Ending Wt: 206

Food Intake	# Calories
Toast	130
Tea with sugar	22
Grape jelly	50
Fresh orange juice (4 Oz)	60
Coffe with cream/sugar	50
Danish pastry (snack)	225
Pizza with extra cheese	500
Beer (2 cans)	400
Pot roast	250
Bread (no butter)	70
Corn (canned)	35
Coffee with cream/sugar	50
Peaches (canned)	75
Apple pie	275
Potato (hash browned)	240
Ice cream (2 scoops)	300
Total	2,682

End of first day

Table 5.1 Daily calorie data sheet.

Activity	Calories/Hour
Carpentry	170
Dancing	275
Dishwashing	80
Driving truck	80
Ironing	75
Laundry	100
Playing piano	60
Reading	33
Resting	14
Running	500
Sewing	35
Sitting	30
Skating	265
Standing	50
Sweeping	110
Swimming	560
Typing	80
Walking	150
Washing floors	90

Table 5.2 Calorie consumption for selected activities

Biological Science: Lesson 6

Elephants vs Mice

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that all body cells are about the same size.

√ emphasize that oxygen and other materials must be able to enter and leave the cell or it will die.

√ explain how the volume of a cell increases faster than the area of a cell.

For Class Discussion:

√ When your arm or leg "falls asleep" what happens to the cell?

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 20-22)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 64-83)

Biological Science: Lesson 6

Elephants vs Mice

Science Concept:

Cell Growth

If there were to be a contest between an elephant and a mouse, which would win? It would depend on what the contest was measuring. For example, an elephant would win if you were measuring height. A mouse would win if you were measuring an ability to go through *small* holes. But which would win if you measured cell size?

Of course, it would depend on which cells you were measuring. But in general, the contest would be close enough to be a tie. This interesting fact is a surprise to most people.

How can an elephant have body cells that are about the same size as the body cells of a mouse? The elephant is so much larger! The elephant is much larger because it has many more cells. The mouse is smaller because it has fewer cells. But the sizes of the two animals' body cells are similar.

How big can a cell get? This information may not have much practical value in your everyday life, but it is interesting. Did you ever see a horror movie that has a single-celled creature? (If not, lets say that you did.) This one-celled "animal" usually begins by eating something small. Then it eats a tree or a car. Later it eats a house. Finally it attempts to eat New York City. As it eats, it grows. And it grows. And it grows some more. But can a one-celled animal keep growing? No, only in the movies. At some point it must separate and make two cells.

Why must it separate? Why can't a cell just keep getting larger? To understand the answer to these questions you must know that:

1. waste is made inside all cells.
2. waste must exit through the surface of the cell.
3. oxygen and other things must be able to get into the cell.

As the cell gets larger, there is so much waste that it can't all get out. This begins to poison the cell. Also, not enough oxygen can get in. So the cell cannot grow any further. Only in the movies can a one-celled creature keep growing forever.

Beyond the Basics:

To better understand cell growth one must use math. If you like math and can square a number (multiply one number times itself), you may want to keep reading. If you cannot do multiplication, it is time for you to take a break and move to another lesson.

Let's assume that you have a spherical ("round") cell. As cells grow in size, their rate of growth slows down until growth stops. One thing that determines cell growth is the relationship between the surface area and the volume of the cell. The surface area is the "wall" around the cell. The volume is the "inside" of the cell. As a cell grows in size, the amount of materials that goes in and out of the cell increases. But the surface area through which the materials must pass increases at a slower rate than the volume.

The surface area increases more slowly than the volume. Looking at the formulas for the surface and volume of a sphere may help you to see this point.

The volume increases as the *cube* of the radius.
Volume = $(1.33) \times (3.14) \times (R^3)$

But the area increases as the *square* of the radius.
Area = $(4) \times (3.14) \times (R^2)$

The radius of a cell is the distance from its center to its edge. (Figure 6.1)

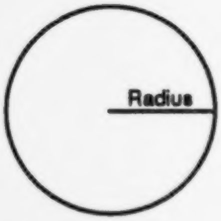


Figure 6.1 Radius of a cell

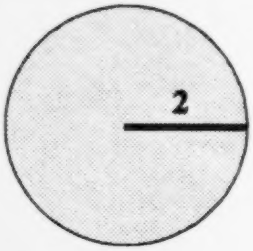


Figure 6.2 Cell with a radius of two

An example may help. Lets begin with a cell that has a radius of 2 units (see Figure 6.2).

It would have an area and a volume approximately as follows:

$A = (4) \times (3.14) \times (R^2)$
$A = (4) \times (3.14) \times (2^2)$
$A = (4) \times (3.14) \times (4)$
$A = 50$ square units

$V = (1.33) \times (3.14) \times (R^3)$.
$V = (1.33) \times (3.14) \times (2^3)$
$V = (1.33) \times (3.14) \times (8)$
$V = 33$ cubic units

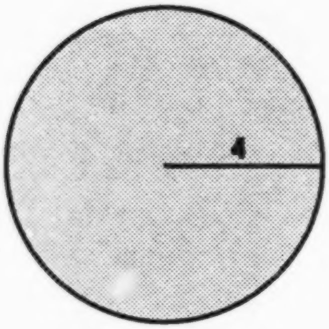


Figure 6.3. Cell with a radius of four

Now lets say that the cell grew. Its radius doubled to 4 units in length. (Figure 6.3)

Now its area and volume would be approximately as follows:

$A= (4) X (3.14) X (R^2)$
$A= (4) X (3.14) X (4^2)$
$A= (4) X (3.14) X (16)$
$A= 200$ square units

$V = (1.33) X (3.14) X (R^3)$
$V = (1.33) X (3.14) X (4^3)$
$V = (1.33) X (3.14) X (64)$
$V = 267$ cubic units

If we now compare the new area (200) to the old area (50), we can calculate that the new area is four times larger.

200 divided by 50 = 4 times larger

If we now compare the new volume (267) to the old volume (33), we can calculate that the new volume is eight times larger.

267 divided by 33 = 8 times larger

This shows that the volume of a cell does increase faster than its area.

Do not worry if you do not understand all of this math. The point that you should know is that cells cannot just keep growing. Most body cells are about the same size. So, large animals like elephants have body cells about the same size as small animals like mice.

Biological Science: Lesson 7

Dangerous Characters

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of life cycles.

√ emphasize that an understanding of life cycles is important in helping us to manage dangerous organisms.

√ explain how the elimination of a host can break the life cycle.

For Class Discussion:

√ If everyone in the country cooperated, would it be possible to eliminate a pest such as the mosquito? Why or why not?

For More Information:

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 311-327)

Biological Science: Lesson 7

Dangerous Characters

Science Concepts:

Life Cycles
Parasites
Disease

Biology is the study of life. This includes both plants and animals. People have always been interested in plants and animals. This is because our survival depends on them as a source of food and oxygen. Without them, we could not exist.

However, living things can also cause problems. Certain kinds of bacteria are good examples of very dangerous organisms. Some can cause illness and disease. The toxin (poison) of one type of bacteria (*Closteridium botulinum*) is extremely powerful and dangerous. It has been estimated that it would only take 15 ounces of this toxin to kill everyone in the world!

Toadstools and mushrooms are another example of dangerous organisms. The 10th edition of the *Guinness Book of World Records* lists the most poisonous toadstool as the *Amanita phalloides*. This yellowish-olive death cap can cause vomiting, delirium, collapse and death just 6 to 15 hours after tasting it! One victim of the death cap is believed to have been Pope Clement VII. He died in 1534.

Snakes are another example of dangerous organisms. Some sources estimate that as many as 40,000 - 45,000 people die each year from snake bites. (Most of these deaths are not in the United States.) It is not clear which snake is *the* most poisonous; however, several are very deadly. For example, one ounce of tiger snake venom could kill about 14,000 people.

In the above examples, it is generally not difficult to form a link between the victim and the cause of death. In other words, Pope Clement VII ate a toadstool, and he died. Although he may have died of other causes such as a heart attack, it is not difficult to determine that the toadstool is poisonous.

On the other hand, not all dangerous plants and animals are easy to discover. Bacteria were not even known to exist until the mid-1800s. Since they are too small to be seen with a naked eye, the invention of the microscope had to come first.

There is yet another problem associated with certain dangerous animals. Some of them have a complex life cycle. This means that during parts of its life, the organism is not dangerous. But during other parts of its life, it can be deadly. This type of life cycle makes it very hard for scientists to discover the exact cause of the disease.

To better understand the concept of a life cycle we will examine a sheep liver fluke. A sheep liver fluke is a flatworm and it is a parasite in many animals, including humans. A parasite is an organism that "steals" its nourishment from another organism. The organism being "robbed" is called the host. Generally speaking, parasites and hosts can be either plants or animals. Parasites can kill a host through starvation, infection or other means.

The flukes' life cycle is complicated. Nobody knows where the life cycle began. That is like trying to determine whether the egg came before the chicken. We do know that the fluke spends part of its life in a snail. Part of its life is spent on the ground or on grass. Part of its life is in a sheep.

The egg is a good place to begin the cycle. The fluke egg can be found in the waste material of sheep. If an egg falls into water, it can hatch into what is called a larva (immature form of the worm). This young flatworm can then enter the body of a certain type of land snail. While inside the snail, the larva passes through several stages. During this process it reproduces by asexual (without eggs and sperms) reproduction. Now there are several worm larvae (larvae is the plural form of larva).

The larvae can now leave the snail and crawl on grass or weeds. At this point a larva can form a cyst. A cyst is alive, but very inactive. Hence, a cyst can survive periods of dryness, heat *etc*. If a sheep eats a fluke cyst, the cyst becomes an active adult flatworm. These worms live in the liver of the sheep. As adults, the worms produce eggs which pass to the intestine. From here they are eliminated from the sheep.

The host (sheep in this case) becomes ill as a result of the fluke. Symptoms include swelling, inflammation, irritability and ill health. In cows the milk production is reduced. Many times the host dies. The economic loss caused by fluke-infected cows, pigs, and sheep has been significant. Sometimes people become infected. This is common in the Orient, and Cuba has had epidemics of human liver fluke.

How can this sort of problem be controlled? The easiest way is to eliminate or remove one of the hosts. In other words, if the snails could be eliminated from the fields where the sheep live, the life cycle of the fluke would be broken. The fluke would die.

The concept of a life cycle is very important to you. It helps you to understand why certain actions are important in the control of specific diseases. For example, there have been requests by public health officials to drain water from old ditches. This can help to control malaria.

How can draining a ditch help to control malaria? To answer that question we should know two things. First, we need to know what causes malaria. Second, we need to understand life cycle of that organism.

Malaria is **not** caused by mosquitoes. This is a surprise to many people. Malaria is caused by a one-celled organism named *Plasmodium*. This organism is a parasite in humans and can cause severe illness and death. It also lives part of its life in a mosquito. It is in the stomach of the mosquito where the malaria organisms grow and develop into an infective form. This infective form moves to the mouth glands of the mosquito. When the mosquito bites someone, the *Plasmodium* is injected into the human. So you see, the life cycle of the malaria organism involves two hosts, mosquitoes and humans. Hence, if we can eliminate the mosquito, we can eliminate malaria. One way to reduce the number of mosquitoes is to reduce the amount of water in puddles, ditches, etc. This is effective because mosquitoes must have water during part of their life cycle.

There are many other diseases that involve a complex life cycle of one or more organisms. African sleeping sickness is another example. This disease is caused by one-celled organisms known as trypanosomes. The life cycle of trypanosomes must include a tsetse fly. It is in the intestines of this fly where the disease-causing organism develops. Although some drugs can be used to treat the disease, the only totally effective measure may be the elimination of the tsetse fly. It is unlikely that you will get African sleeping sickness in the U.S. This example is mentioned to show the world-wide problem associated with complex life cycles.

Farmers and gardeners can also benefit from a knowledge about life cycles. There are several fungi that cause plant disease. One such group is called "rust fungi." There are over 2,000 known rusts that can cause disease in plants. About 250 of these rusts are parasites on wheat, oats, barley, and other grains. They cause millions and millions of dollars of damage to crops each year.

One of the most well know rusts is wheat rust. This fungi appears on the wheat in late spring. Throughout the summer it will produce another form of itself and reinfect additional wheat. By late summer, much of the wheat has been infected and destroyed. In late summer the fungi will produce another form of itself that cannot infect wheat. This form, know as "black spores," will remain dormant (inactive) throughout the winter on the wheat stubble that is on the ground. Early in the spring still another form of the fungi is produced. This form can be blown by the wind. If this form of the fungi lands on the common barberry plant (not the cultivated Japanese barberry), the fungi will infect the barberry. The fungi on the barberry plant will produce yet another form of the wheat rust. This can also be blown by the wind for several miles. If this form of the rust lands on a young wheat plant, the cycle begins anew. All told, there are four major forms of the wheat rust. Each plays a unique part in the life cycle of the rust. If the barberry plant could be eliminated, the life cycle of the wheat rust would be broken. Millions of dollars in crops could be saved.

Smuts are another example of a plant parasite. Corn smut reduces sweet corn production. An understanding of the smut's life cycle will help you to control this garden parasite. Since the smut fungi does not need two hosts, you cannot use the concept of "host elimination" to control this fungi. Instead, you can control this parasite by burning infected plants, plowing under the stubble after the corn is cut, and destroying the unused stalks and leaves after the corn is picked.

In summary we should remember that most of the plants and animals are essential for our survival. However, some of theses organisms are "dangerous characters." In either event it is helpful to understand their life cycles. This understanding can help us to promote the growth of the beneficial organisms. It can also assist us in the control or the elimination of the dangerous organisms.

Something to Try

During the summer, find a corn field and ask permission to walk through it. As you walk through the field, look closely at the ends of the ears. See if you can notice large, dark growths. These are probably some form of corn smut. (Do not confuse these growths with the hair-like silk that grows out the top of each ear of corn.)

If a field has wheat, you can look for signs of wheat rust. In late spring or early summer watch for tiny blisters along the surface of the stems and leaves. The color of the blisters will be reddish-orange. These are the spores (spores look like tiny seeds) that can reinfect more wheat. Late in the summer look for black spores. These are the spores that lie dormant over the winter.

If you can find a barberry plant in the early spring, look for honeycomb-like cups on the surface of the leaves. This is where the spores that infect wheat will be produced.

Biological Science: Lesson 8

Who Determines Sex?

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept that each offspring is the result of a combination of an equal number of genes from each parent.
- √ emphasize that the sex of a human child is not controlled by the mother.
- √ explain why females do not become bald as frequently as males.

For Class Discussion:

- √ Do you think that it would be a good idea to develop a way for parents to be able to select the sex of their child? Why or why not? What do you think would happen?

For More Information:

C. Heimler, *Principles of Science, Book Two,* Charles E. Merrill, Columbus, OH, 1979. (pages 104-123)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 118-169)

Biological Science: Lesson 8

Who Determines Sex?

Science Concepts:

Chromosomes
Sex Determination

Is it the mom or the dad that determines the sex of the children? Think of a family with three children. The odds are only one in eight that all three children are of the same sex. If a family has four children, the odds are one in sixteen that all four children are of the same sex. We know that *about* half of the babies being born are males and half are females. But why is that true? Is it because of the genetics of the mother? Is a child's sex determined by the father? Or is the sex of the child just "chance" and not related to anything about either parent?

Sometimes this question becomes an argument between a husband and a wife. Imagine a couple that wanted a son and a daughter. Their first three children were girls. Both parents loved the girls, but they also wanted a son. They decided to try again. Now there are four daughters ! Can't you imagine some couples having a friendly argument over "who made all those baby girls?" The man blames the woman. The wife blames the husband. About all they can agree on, is that they have four beautiful girls, but no boys.

What is the answer to their question? Prior to the early 1900s nobody knew why some babies were female and other babies were male. But now we know. It has to do with the type of chromosomes that men and women have in their cells. (Chromosomes are made up of genes. Genes control the passing of traits from parents to offspring.) We get our chromosomes from our parents.

Every normal body cell of a person has 23 pairs of chromosomes. One chromosome of each pair comes from the mother's egg. The other comes from the father's sperm. The two chromosomes of each pair work together to determine the traits that a baby has inherited. Eye color would be an example of a trait that was determined by both parents. In fact, *most* traits are determined by chromosomes from both parents.

Sex is not determined by chromosomes from both parents. One pair of chromosomes is called "sex chromosomes." One looks like an "X" and the other looks like a "Y." Males have one "X" and one "Y" chromosome in each body cell. Females have two "X" chromosomes and no "Y" chromosomes. As a result, men can produce sperm that can have either an "X" or a "Y" chromosome. But women can only produce eggs that have an "X" chromosome. If a sperm with an "X" chromosome combines with an egg, the baby will be a boy. But if a sperm with a "Y" chromosome combines with an egg, the baby will be a girl. This is why people say that it is the father who determines the sex of the baby.

It is interesting to note that in some animals the situation is reversed. For example, *male* birds have two chromosomes of the same type. It is the sex chromosome in the *egg* that determines the sex of the bird.

Since the "X" and "Y" sperm are not identical, some people have thought about ways to select one or the other type of sperm. If this could be done, one could choose the sex of the baby. Most of these methods are not in wide use and could be called, "experimental."

A Little Bit More

Gender, a person's sex (male or female), is not the only trait that is influenced by the sex chromosomes. We also have sex influenced traits. A sex influenced trait works one way in males and a different way in females. For example, some forms of baldness are sex influenced. If a female inherits a pair of "baldness genes," she may not become bald. But that same set of genes in a male can cause baldness.

Sex-linked is still another type of genetic trait. A sex-linked trait occurs more frequently in one sex than in another. For example, red-green color blindness occurs in about 8% of the males. But this form of color blindness almost never occurs in females.

There is a difference between a sex-linked trait and a sex-influenced trait. In a sex-linked trait the males and females have different types of genes that cause different characteristics in each sex. But in a sex-influenced trait, the genes are the same in each sex, but cause a different characteristic.

Something to Try

Survey several different families that have four or less children. Determine the number of boys and the number of girls. When you finish collecting your information (data), make four tables similar to Tables 8.1 through 8.4 in this book. Compare your results to the "expected" results in the book. You may want to combine your data with others who have done a similar survey. This is especially true if you surveyed less than 30 families. The larger your sample size, the better your data will match Tables 8.1 - 8.4.

If you have trouble reading the following tables, this may help. Use Table 8.1 for families with only one child. Use Table 8.2 for families with two children, etc. The numbers across the top tell how many boys are in the family. The numbers down the side tell how many girls are in the family. The number inside each box represents the expected percent of families with that number of girls and boys. For example, in Table 8.3 one can see that we expect about 12.5% of the families with three children to have 3 boys and 0 girls. It is also true that we

		# BOYS	
		0	1
# GIRLS	0	NA	50%
	1	50%	NA

= Not Apply

Table 8.1 Expected percents for a one-child family

		# BOYS			
		0	1	2	3
# GIRLS	0	NA	NA	NA	12.5%
	1	NA	NA	37.5%	NA
	2	NA	37.5%	NA	NA
	3	12.5%	NA	NA	NA

Table 8.3 Expected percents for a three-child family

expect the same percentage of families to have 3 girls and 0 boys.

If you do not know how to calculate a percent or how to complete your tables, follow this example for Table 8.2. First, divide the number of families that have 0 boys and 2 girls by the total number of families with 2 children. Your answer will be a decimal. To get a percent multiply that decimal by 100. Place that percent in *your* Table 8.2 where the "0-boys column" meets the "2-girls row."

		# BOYS		
		0	1	2
# GIRLS	0	NA	NA	25%
	1	NA	50%	NA
	2	25%	NA	NA

Table 8.2 Expected percents for a two-child family

		# BOYS				
		0	1	2	3	4
# GIRLS	0	NA	NA	NA	NA	6.3%
	1	NA	NA	NA	18.8%	NA
	2	NA	NA	50%	NA	NA
	3	NA	18.8%	NA	NA	NA
	4	6.3%	NA	NA	NA	NA

Table 8.4 Expected percents for a four-child family

Next divide the number of families that have 1 boy and 1 girl by the total number of families with 2 children. Place this answer, as a percent, into the square where the "1-boy column" meets the "1-girl row."

Finally, divide the number of families with 2 boys and no girls by the total number of families with two children. Place this answer in the correct square. This will complete Table 8.2. In a similar way complete your other tables.

The purpose of doing all these tables is to see if your data matches the book's data. If your data is different from the data in the book, can you think of some reasons why this happened? The most probable reason is that you did not include enough people in your survey. It does not matter how your data came out. This activity was just for fun.

The main purpose of this lesson is to learn that it is the genes of the male that determine the sex of a baby. The genes of the baby's mother do not determine the sex of the child.

Biological Science: Lesson 9

For the Birds

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept that birds, like many animals, have very interesting behaviors and adaptations that allow them to be very efficient in what they do.
- √ emphasize the ways in which birds are well designed for flight.
- √ explain how a "magnetic sense" would be used by birds during migration. Also, explain why the sun and stars by themselves do not provide enough information for migration to be successful.

For Class Discussion:

- √ Which birds, if any, do you think should be protected by law. Explain your answer.

For More Information:

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 378)

Biological Science: Lesson 9

For the Birds

Science Concepts:

Bird Anatomy

Bird Behavior

As a group, birds are a very common animal. There are over 25,000 different kinds of birds. They seem to be everywhere. Certain species of birds, such as pigeons, live in the city. Penguins live near the South Pole. Sea Gulls live near the ocean. Ravens live in the mountains. Road Runners live near deserts. It is difficult to find a place where no birds live.

Birds range in size from the very tiny hummingbird to the large ostrich. Hummingbirds weigh about one-tenth of an ounce, while an ostrich weighs about 125 pounds or more. The largest bird is about 20,000 - 30,000 times larger than the smallest bird. This seems like a very wide difference. But the difference is even greater for mammals. The *largest* mammal (200,000 pound blue whale) is about 22,000,000 times larger than the *smallest* mammal (one-seventh ounce shrew). Hence, birds can be said to be similar in size to one another.

Although birds are very common, most people do not fully understand very much about them. The purpose of this lesson is to describe some interesting features about birds.

Eyesight

You probably realize that some birds have excellent vision. But the following story may still amaze you. It is from Eric Roberts' delightful little book, *Oddities of Animal Life*. The story is about a scientist who was observing birds. One day he was standing at the side of a lake and saw an eagle. The eagle was flying at a very high height above the lake. "Suddenly, the eagle plunged diagonally downward in an unswerving glide-dive for a distant area of the shore where it seized a fish it had detected." A careful measurement showed that the distance from where the eagle seized its prey to the spot over which it had been soaring when it first saw the fish was just about three miles! Although not all birds can see this well, it is generally true that birds have excellent vision.

The eye of a bird is also able to change its focus very quickly. One instant it can be looking at a potential enemy in the distance. The next moment it can focus on a crumb of bread just beneath its foot. This is different from some animals that cannot change their focus.

Did you ever travel in a rapidly moving vehicle without a windshield? For example, did you ever stand in the back of a pickup truck while it was moving at highway speeds? What happens to you eyes when you look forward? Most people find that their eyes form tears. This makes it very difficult to see. How can birds fly at speeds of 40 or 60 miles per hour without loosing their vision? The answer is that they have a "third eyelid." This eyelid protects the eye and keeps it moist and clean. This membrane is almost clear, so birds can see through it. It is like being able to see and having your eyes closed at the same time. Did you ever notice that birds sometimes look like they are winking at you? The winking appearance is from the "third eyelid" moving across the eye.

Many birds have one eye on each side of its head. (The owl is a noticeable exception.) This means that they can't look forward very well. But they are able to see in two directions (left and right) at the same time. When a robin is looking for worms, it cocks its head to one side. Some people claim that this is to allow the bird a better chance to hear the worm's movements. This is not true. A robin cocks its head so that one of its eyes will be looking down toward the ground.

Some birds such as the swallow have a special eye. It is "split" so that it can look sideways and forward at the same time. These birds can fly after insects and look to the right and to the left at the same time. Their visual image must look like a split TV screen looks to us.

Kingfisher's eyes are still another example of special features. When a kingfisher is sitting on a tree branch, it looks left and right like a robin. But when it dives under water to catch a fish, it can use both eyes to look forward. This gives the kingfisher a 3-dimensional view like we have.

Birds can see colors. This isn't too surprising since so many of them are so very colorful. Why would nature provide colorful feathers if it didn't help other members of the species to recognize them? But they may not see all of the colors that we see. It seems that they can see reds, greens and yellows but have trouble with blues and violets.

Flying

Flying is a remarkable activity. Birds can fly because they are light weight and have high power. This comes from having hollow bones, feathers, wings, a remarkable system for breathing, large heart and powerful breast muscles.

A bird's weight is low for several reason. The main reason is that its bones are hollow. One scientist reported that the skeleton of a 7-foot frigate bird weighed only four ounces, which was less than the weight of its feathers. Nevertheless, a bird's frame is very strong and elastic.

There are other reasons why birds are very light in weight. They have a reduced reproductive system. The female has only one ovary. (Most female animals have two ovaries.) In addition the sex organs of both the male and female shrink in size and weight during the non-breeding season. For example, in starlings the sex organs weigh 1,500 times as much during the breeding season as during the rest of the year.

In addition, birds have heads that are very light in proportion to the rest of the body. This is because they don't have teeth. Without teeth there is no need for heavy jaws and jaw muscles. A pigeon's skull weighs much less than 1% of its total body weight.

Birds usually fly at an altitude of less than 1,000 feet. But there are reports of birds flying much higher. For example, curlews have been seen flying at 20,000 feet. Then there is the picture of a sunset which shows a flock of geese flying at an estimated height of 29,000 feet. (But some experts doubt that estimate.) The highest documented altitude listed in the 10th edition of the *Guinness Book of World Records* is 26,902 feet. This is over 5 miles high! It should be pointed out that people and other animals begin to have problems with a lack of oxygen when they get to an elevation of only 10,000 to 13,000 feet.

Streamlining and Speed

Birds are very streamlined. They have an angular body that cuts through the air. The sleek feathers help to smooth the bird's body so that it can slip through the air with minimum resistance. The outside of the birds' body is sleek. They have no ear lobes sticking out. They can "retract" their feet and legs while flying.

Birds are the fastest animals. With no wind in any direction, "garden birds" (sparrows, blackbirds, thrushes, *etc.*) easily fly at speeds of 25 to 35 miles per hour. Ducks and similar birds fly at 45 to 60 miles per hour. The swift has been timed at 90 miles per hour.

Diving birds are the fastest of the birds. A gannet can dive at speeds of over 100 miles per hour. The streamlined peregrine falcon is believed to dive at speeds in excess of 180 miles per hour. An airplane pilot was diving at 170 miles per hour. He reports being passed by a diving peregrine falcon "as if the airplane was standing still!" According to reports, the fastest reported speed by a bird was 219.5 miles per hour. The bird was a spine-tailed swift. The speed was timed with a stopwatch over a two-mile course in India. Some of the fast-flying birds have special baffles in their nose to protect their lungs from excessive air pressure.

(It should be noted that according to the 10th edition of the *Guinness Book of World Records*, the fastest **reliably** measured speed of an animal is 106.25 miles per hour. This was by a bird known as the spine-tailed swift.)

Even underwater, some birds are excellent swimmers. The Antarctic penguin has been clocked at 22 miles per hour while swimming under water.

A Little Bit More

Birds have a very high body temperature. Their temperatures are frequently between 107 and 114 degrees Fahrenheit. (The body temperature of humans is about 98 degrees.) In addition, they have rapid heart rates. For example, the heartrate of the hummingbird is over 600 beats per minute. (The heart rate for humans is about 72 beats per minute.)

The high body temperature and rapid heartbeat of birds allows them to live intense , but short lives. The typical songbird lives less than two years in the wild. However, some of the larger birds with lower heart rates live much longer. For example, there is a case where a female eagle-owl lived to be 68 years old. And a parrot is reported to have lived for 72 years.

Most birds are never out of breath while flying. In fact, it can be said that birds "fly into breath." In addition to lungs, birds have air sacs and hollow bones that serve to exchange oxygen for carbon dioxide. This helps to explain how birds can breathe easily at high altitudes where most mammals could barely function.

Some birds lack a good blood supply to their breast muscles. The white meat of a chicken and a turkey is the result of only a few dark blood vessels in this part of the body. These birds cannot fly very far and they tire easily. But they have a good supply of blood to their legs and they can run for long distances.

A ruffed grouse is another example of a bird that lacks a good supply of blood to its breast muscles. When this bird has been flushed four times in rapid succession, it gets tired. You can then pick it up with your hands.

Many birds migrate long distances each year. They use the sun, stars and the magnetism of the Earth to help find their way. (Birds have a sense of magnetism.) During migration birds easily fly non-stop for 2,400 miles. The Arctic tern migrates from Russia to Australia. This is a distance of about 14,000 miles.

During its non-stop flight from Labrador to South America, the golden plover loses about 2 ounces of weight. This efficiency is similar to flying a 1,000 pound airplane 20 miles on a pint of fuel.

Something to Try

This is a long-term project. Build or buy a bird feeder. Put the bird feeder in a protected location near your house. Buy or borrow a book that will help you to identify the different kinds of birds. For one year, watch and identify the birds that come to your feeder.

Although there are over 25,000 different kinds of birds, you will be lucky if you can see 100 of them. This is less than 1% of the total.

After one year of watching birds, you will see why bird watching is a life-time hobby enjoyed by thousands of people. It may surprise you to learn that the popularity of birdwatching is growing very rapidly. The "typical" birdwatcher is male, between 30 and 40 years of age, and lives in one of the Rocky Mountain states.

Biological Science: Lesson 10

Amazing Animals

Teacher's Page

Lesson Objectives:

√ develop the concept of animal behavior so that your students realize that animal behavior is both interesting and complex.

√ emphasize that a better understanding of animals can improve the lives of people.

√ explain what is meant by "problem solving" and disscuss why it is a higher level of thinking than instinct or learning.

For Class Discussion:

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 518-539)

For More Information:

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 518-539)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (pages 354-383)

Biological Science: Lesson 10

Amazing Animals

Science Concept:

Communication
Animal Behavior

You have probably heard people say that they enjoy nature and the outdoors. Maybe you are one such person. For some reason, most people have a natural interest in animals and natural events relating to animals. In fact, outdoor activities that relate to nature are very popular. Millions of people visit national and state parks every year. Campgrounds are filled during the summer months. Popular fishing streams are overcrowded during fishing season. In Pennsylvania hunting is a very popular sport. During deer season some woods seem to have more hunters than deer. Rivers, lakes and other bodies of water are usually crowded with people and boats. This makes it very difficult to see and to appreciate the wonders of nature. Even people in the city want to experience nature. This is a reason why zoos are so popular. When you talk with people about their special outdoor interests, you will find that they do not all agree. For example, some people would like to have more trails and campgrounds built in the national parks. They argue that this would allow more people to enjoy the great outdoors. On the other hand, some people argue against that idea. These individuals point out that when you get too many people into the woods, the animals seem to disappear, and nature is "destroyed." These are difficult issues. For problems like these, both sides are partially right. The solution is to find the correct balance between the two positions. This is not easy.

Although various groups disagree about the best way to conserve nature, they do have at least one thing in common. That is, they all agree that the more you know about nature, the more you appreciate its wonders.

The following descriptions are given to illustrate interesting behavior in some of nature's amazing animals.

Thoughtful Birds

Animals have several levels of behavior. For example, they can have reflex behavior. When an object comes close to an eye, the eye will blink. This is a reflex. A higher form of behavior would be an instinct. We believe that animals are born with the knowledge of how to do some things. We call this knowledge an instinct. When a baby duck begins to swim, this is probably an instinct. Some animals can learn to do certain tasks. This is a learned behavior. Circus acts and movies are filled with animals that have learned to do specific tasks. So it is clear that animals can learn.

Most people would agree that animals can have reflexes, instincts, and learned behaviors. However, some people believe that only humans can do true problem solving. Higher level thinking such as problem solving is not easy to demonstrate. There is sometimes disagreement as to whether a certain behavior is problem solving or another form of behavior such as instinct or learned behavior. Questions of this type are very interesting, but beyond the scope of this lesson. Nevertheless, the following story from *Oddities of Animal Life* will give you a sample of what many people would consider to be true problem solving.

Several families of house sparrows were living in a garage. Unfortunately, one of the birds managed to get its head stuck in the entrance hole which was high on the wall of the garage. The bird's body was outside, and its head was inside. It struggled, but could not move in either direction The person who owned the garage tried to free the bird with a long bamboo cane. This effort did not work. The bird remained stuck.

Eric Roberts continues the story as follows. "Then a most extraordinary thing happened. Another sparrow, which was perched on the garage roof, suddenly took off and dived down with its wings closed. As it came level with the bird that was trapped, it made a desperate grab at its tail, hung on grimly for a few seconds, then had to let go, and flew down to earth. In a moment, however, it was up on the roof again, and taking off for a second try.

Several times the sparrow dived down in this way, always with its wings folded so that it would travel faster, and each time it hung on to the trapped bird's tail for as long as it could. But the scheme didn't work.

So, believe it or not, a second bird come to the rescue. This little chap, if you please, dived down a second or two after the first bird, and hung on to *his* tail, making three birds in a row! They did this several times, and at last their efforts were rewarded. The unfortunate sparrow was pulled free, and down it fluttered to the ground, not much the worse for its ordeal except for a few missing feathers, slight damage to one leg -- and, I shouldn't be surprised, a jolly sore neck!"

This story raises several interesting, but unanswered questions. For example, how did the two rescue birds know that the first bird was in trouble? Next, how did the first rescue bird know that pulling on the tail of the stuck bird was the correct thing to do? Third, by what means, if any, did the two rescue birds communicate with each other? Fourth, did the unstuck bird appreciate the help of the other birds, and could it offer any thanks? Finally, did the unstuck bird learn not to go into that hole again? These questions are for you to think about. You may also want to discuss your answers with others who may have different opinions.

Perhaps humans are not alone in their ability to do problem solving. Many scientifically documented stories of problem solving exist in the biological journals and books. Perhaps "lower animals" are more intelligent than we sometimes believe.

Communication in Honeybees

Did you know that honeybees must fly about 50,000 miles in order to gather enough nectar to make one (1) pound of honey? That is almost twice around the world. Of course, one bee does not do all of the work. Tens of thousands of honeybees live together in groups called colonies or swarms.

Careful research and observation has shown these colonies to be very social. Highly effective communication takes place among the bees. One example of this communication is the way one bee can direct other bees to a new source of nectar. When a bee discovers a large field of flowers, it returns to the hive and does a dance. The dance is in the shape of a figure "8." The pattern of the dance gives other bees information about where the field of flowers is located. The position of the dance pattern is related to the position of the sun. This allows the bees to use the sun as their compass. Since the hive is dark on the inside, the bees must use their antennae to feel the pattern of the bee doing the dance. It is also probable that sound from the bee's wings also provides information about the distance to the flowers.

It is interesting to note that the dance done by a bee can be "read" by people. That is, if a scientist sees a bee's dance, he/she can tell how far, and in which direction, the flowers are located.

Sexton Beetles

Did you ever wonder what happens to all of the dead mice, birds, chipmunks *etc.* that die in the woods? Most of these dead creatures are eaten by scavengers, bacteria and other animals. However, have you ever heard about the sexton beetle?

Worldwide, there are about 100 different species of sexton beetles. The adult sexton beetle is usually less than an inch long. It is colorfully marked with alternating bands of black and orange colors.

The sexton beetle lives just below the surface of the ground. Its antennae stick up through the surface and can detect the odor of decaying flesh. When it smells a dead animal, the beetle will immediately fly to that location and wait for a member of the opposite sex to arrive. It will fight off members of its own sex. Sometimes several of these beetles find a dead animal at the same time. When this happens, it looks like a war with all of the males fighting all of the other males. And all of the females fighting all of the other females. Weaker individuals will give up and leave.

When only one male and one female remain, does the business of burying the dead animal actually begin. (Keep in mind that the sexton beetles are less than an inch long. The animal being buried could be as large as a squirrel, bird, mouse *etc.*) The two sexton beetles start their task by burrowing under the dead animal. The loose soil is pushed out of the burrow. The digging process is repeated several times, and soon the two beetles have created a trench. When the trench is large enough, the dead animal falls down into the hole. The beetles keep removing soil until there is a chamber around the dead animal.

At this point the female lays her eggs near the dead animal. The male beetle then leaves. His work is done. The female remains to guard her eggs. They hatch out in a few days. The baby beetles (larvae) immediately sense the corpse, and they begin to eat the flesh from the inside. Sometimes the mother assists the larvae in breaking off chunks of flesh. They eat everything but the bones, hair and feathers. This is one reason why you do not see millions of small, dead animals laying around in the woods.

Because of the task that is performed, the sexton beetle is called the burying beetle. Their job is not a very pleasant activity. But it is one that is important in nature's scheme of things.

Imprinting in Ducks

Have you ever noticed that ducklings follow their mother? How do they know which object to follow? Why don't they follow a boat or a log? The answer to this question is related to a process known as "imprinting."

Imprinting is when an experience in early life determines the social behavior in later life. The concept of imprinting has been studied mainly in birds. Let us look more closely at a few experiments that have been done to demonstrate how a duckling knows to follow its mother.

The subjects in this experiment were mallard ducklings. The laboratory included a walkway for the ducklings. The walkway had walls so that the ducklings could not wander away. The walkway was about 12 inches wide and was in the shape of a circle. On the walkway there was a decoy duck made of wood. This pretend duck could be made to move around the walkway by using a motor-driven arm that pivoted from the center of the walkway.

A duckling that had never seen another duck was placed on the walkway. The decoy duck was moved slowly around the circle. The duckling was allowed to follow the decoy for about 10 minutes. Later, the duckling was given an opportunity to move toward the decoy or toward real ducks. It was found that the duckling liked the decoy better.

This process is called imprinting. There is a critical age at which time imprinting must take place. For ducks this age is about 16 hours after hatching. In other words, whatever object a 16 hour old duckling follows will become the "mother" in the mind of the duckling.

Does imprinting occur in any animals besides ducks? Yes. As early as 1958 the concept of imprinting had been shown to exist in guinea pigs, geese, sheep, turkeys, pheasants, quail and chickens.

It is interesting to note one researcher's (Eckhard Hess) comments about imprinting and humans. He stated that human babies must have a certain amount of attention and handling during a critical period of its infancy. This period is probably not as sharply defined as the 14 to 16 hour period in ducks. But he suggested that the period for humans may be within the first six months of life. This suggests the importance of holding, cuddling and generally being with young human babies.

A Little Bit More

There are thousands (possibly millions) of interesting stories about animals. The more we study animals, the more surprised we become. And as we gain information, we learn how to appreciate the amazing animals that are all around us. Furthermore, an understanding of animal life sometimes helps us to better understand our own lives.

If you enjoyed this lesson, you may want to go to the library to explore some or all of the following questions:

√ How are eyes specialized for seeing at night?

√ How do moths use ultrasound to avoid bats?

√ How do fish use a sense of electricity to identify objects?

√ How can a camel go days without any water? (The hump is not the answer.)

√ How can animals walk on snow and ice without freezing their feet?

√ What is interesting about the battle between a tarantula and its arch-enemy, the digger wasps?

√ Of what importance is the cleaning behavior of certain animals?

√ How do fire flies and certain fish glow?

√ How can the green turtle migrate over 1,400 miles without getting lost?

√ How do ants find their way back to their anthill?

√ How do males and females of certain species find and recognize each other?

√ What is the curious behavior of the stickleback fish?

√ How did the lovebird get its name?

√ How do butterflies migrate hundreds of miles?

√ How do animals hide?

√ How does a bat's radar work?

√ How do snakes use heat to find their prey?

√ After several years at sea, how do salmon find their way back to the stream of their birth?

√ How do birds sense the Earth's magnetism?

√ Why don't bats get into the hair of people?

√ Why don't you get warts from a toad?

√ How does an eel make electricity?

Physical Science: Lesson 11

How Far is the Storm?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept that light and sound travel at different speeds.
√ emphasize how fast light travels through air.
√ explain why temperature changes the speed at which sound travels.

For Class Discussion:

√ Would sound travel faster in water or in air? Why?

For More Information:

C. Heimler, *Principles of Science, Book One,* Charles E. Merrill, Columbus, OH, 1979. (67-77)

J. M. Pasachoff *et. al., Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (pages 323-328 and 364-371)

Physical Science: Lesson 11

How Distant is the Storm?

Science Concepts:

Speed of Sound
Speed of Light

It can be dangerous to be in an electrical storm. If you are playing golf during a storm, you could be hit by lightning. This is also true for people working in a field. This is also true for people who are at the beach. Many people are at risk during an electrical storm. We can't stop our work or fun everytime a thunder cloud is seen in the distance. But we should stop if the storm comes too close, and we are in danger.

It would be nice if we could tell when a storm is coming. Sometimes we can see or hear a storm, but it may never get to us. Most people do not like being in a thunder storm. Maybe this is why there are many ways to guess when a storm is coming. Some people think that they can tell when a storm is coming by looking at tree leaves. They say that when leaves are bottom side up, bad weather is coming. Others know when a storm is coming by looking at the clouds. Less light from the sun is yet another way to tell when a storm is coming. Some people use their senses to warn them of bad weather. For example, some people think that they can "smell" a storm. Others "feel" a storm through pain in an arm or a leg joint. These ways of guessing when a storm is coming may not always work.

There is a way to know for sure if a storm is moving toward you. You can also guess the distance to the storm. Here is how to do it.

1. Watch for lightning.
2. When you see lightning, begin to count seconds. (For example - one thousand one, one thousand two, etc)
3. Listen for thunder.
4. When you hear thunder, stop counting.

How many seconds did you count between the lightning and the thunder? For each second, the storm was about one-fifth of a mile away. (A fifth of a mile is 1,056 feet. This is about one lap around a football field.) If you counted five seconds, the storm was about one mile away.

The rule that always works is to multiply the seconds by 0.2. This will tell you the distance in miles. Or, you can multiply the seconds by 1,056 to find the distance in feet. (Ask for help if you need it.)

For example, if we counted eight seconds we would multiply 8 times 0.2 and get 1.6 miles.

$$\begin{array}{r} 8 \\ \times \quad \underline{.2} \\ 1.6 \text{ miles} \end{array}$$

Or, we could multiple 8 seconds times 1,056 and get 8,448 feet.

$$\begin{array}{r} 1056 \\ \times \quad \underline{8} \\ 8448 \text{ feet} \end{array}$$

The reason that this system works is because we know how fast light and sound travel. Lightning is a form of light. Thunder is a form of sound. Since light travels faster than sound, we see the lightning before we hear the thunder. Light travels very, very fast. It gets to us almost as soon as it is made. Sound is much slower. It takes time for sound to get to us. The longer you wait for the thunder, the farther it is to the storm.

But how can we tell if the storm is moving toward us? Easy.

1. Count the time between lightning and thunder.
2. Wait about 3 minutes.
3. Count the time between lightning and thunder.
4. Compare the second time to the first time.

If the second time is less than the first time, the storm is moving toward you.

Head for cover!

Beyond the Basics

The preceeding calculations are just estimates. To be more exact you must know:

1. The speed of sound changes as the temperature changes. For each Fahrenheit degree increase, sound travels about 1.11 feet per second faster.
2. At 32 degrees F sound travels (in air) at 1,090 feet per second.

Practice Example:

The outside temperature is 70 degrees Fahrenheit. You hear the sound of thunder eleven seconds after you saw the lightning. How far is the storm?

Answer:

We can estimate the distance to be 11,616 feet (2.2 miles) by multiplying 11 seconds times 1,056 (see 2.,above).

To be more accurate we must consider the temperature.

At 70 degrees sound will travel 42.18 feet/second faster than at 32 degrees (1.11 times 38 degrees increase).

We add the increased speed of 42.18 to the base speed of 1,090 and get 1,132 feet per second. This is the speed of sound at 70 degrees.

Now multiply 1,132 (the speed of sound at 70 degrees) times 11 seconds. Our answer is 12,452 feet (2.36 miles).

Something to Try

When you have a storm in your area, use the above method to find out if the storm is moving toward you. Then look at the clouds. Are they also moving toward you? Sometimes there are layers of clouds. One layer can move toward you, and another layer can move away from you.

Physical Science: Lesson 12

Is it Frozen?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of freezing points.

√ emphasize that water is one of the few liquids that is more dense in its liquid form than in its solid form.

√ explain density in terms of volume and mass.

For Class Discussion:

√ If ice did not float, would anything be different in your life? Explain your answer.

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 47-56)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (pages 154-162)

Physical Science: Lesson 12

Is it Frozen?

Science Concepts:

Characteristics of Ice
Lowering the Freezing Point of Water

You may already know that materials can exist in three forms. These forms are solids, liquids, and gases. In most cases the solid form of the material is more dense than the liquid form. For example, *solid* carbon dioxide (dry ice) weighs more per cubic inch than does *liquid* carbon dioxide.

Ice is an important solid. It is frozen water. Ice can be used for fun, but it can also be a serious problem. Lets examine some things about ice.

Ice is different than most other solids. Ice (solid) is less dense than water (liquid). This means that ice can float on water. This is very important - especially to fish. If ice did not float, all of the fish would be killed. Sheets of frozen water would sink to the bottom of the lakes and kill the fish. This would also reduce the food supply of people who need fish to survive.

Killing fish is not the only bad thing that would happen if ice did not float. If all of the ice sank to the bottom of the lakes, rivers and ponds, the sun's rays could not melt it. Over several years, an ice build-up could develop. The world's oceans, rivers and lakes would turn from water to ice! Without doubt, this would have changed history.

You may already know that water expands as it freezes. But just how much does water expand? The answer is that water expands by about one ninth of its volume. In other words you could get 10 quarts of ice from 9 quarts of water! It is clear that ice takes more space than water.

Think of a car's radiator or a water pipe in your house. Both of these have water in them. Both are made from metal. Neither can expand very much. So when the water freezes, the radiator or pipe must break. There is no other way for the ice to get enough space for itself.

But is the ice really strong enough to break something as rigid as a metal radiator or pipe? You better believe that it is possible. The following experiment will show you the power of freezing water. A quarter-inch thick cast-iron container was filled with water. The iron container was placed in dry ice to freeze. As the water froze, it expanded. Lots of energy was pushing against the inside wall of the iron container. The container exploded! Some of the iron was hurled across the room and into a steel door almost 20 feet away.

Another characteristic is the smoothness of ice. This results in a lack of friction between the ice and whatever is on it. Although this can be great fun for ice skaters, it can cause nightmares for drivers. It can also cause problems for people who have to walk on ice. Each year there is a lot of damage, injury and death resulting from accidents due to ice.

A Little Bit More

Is there anything that we can do to control the destructive force of ice? Luckily, the answer is, "yes."

The two most common forms of control are prevention and anti-skid materials. The anti-skid materials are easy to understand. We put sand or gravel on the ice to keep our cars and feet from slipping. This does nothing more than increase the friction. We can also increase the friction by using tires or boots that do not slide very well on the ice. Another way to increase friction is to put studs in our tires to "grip" the ice. Some people use chains on their tires to achieve the same result. In fact, you can do the same thing for your shoes. You do this by buying little "chains" and/or metal "studs" that go on your shoes.

Another way to control ice is to prevent it. This can be done in several ways. For example, you can add antifreeze to your car's radiator. This form of protection does not absolutely prevent ice. It lowers the temperature at which the ice will form. But if it gets cold enough, the water can still turn to ice.

You can tell the temperature at which liquid will freeze by using a tool called a hygrometer. You can buy one of these in most auto stores for under $10. They are very easy to use. They help you know if your car's radiator needs more anti-freeze.

A chemical such as salt can also help prevent ice. We put salt on roads and sidewalks to keep the water from turning into ice. Salt can also melt snow and ice. When salt is in contact with snow or ice, the salt begins to dissolve. This process absorbs heat. The heat comes from the air. Then the snow begins to melt. If the air temperature is too low, the salt can't get enough heat to dissolve. Then the snow does not melt. This is why the road crews do not spread salt on days when the temperature is very cold.

Salt does help keep our roads free from ice. But there is a disadvantage of using salt to control ice. Salt causes metal to rust and tends to "eat" holes in concrete.

As mentioned earlier, frozen pipes are also a problem. There are a couple of things that you can do to keep your pipes from freezing. On very cold nights you can let the faucet drip. Although this wastes water, it will help to keep the pipes from freezing in two ways. First, moving water is less likely to freeze. Second, you will bring into your pipe relatively warmer water from the supply line that is under ground. (Outside water pipes are usually below the freezing line of the soil so they are warmer.)

Another way to keep pipes from freezing is to wrap your pipes with insulation. This will help to keep the heat of the water inside the pipes. You can also buy an "electrical wrap" to put around your pipes. This adds heat to the pipe and helps to keep the ice from forming.

Another interesting feature about ice is the way we use it for keeping our drinks cool. Does ice *add* cold to our drinks? No, it removes heat. Here is how the process works. When we put the ice into a warm drink, the ice begins to melt. This process of changing from a solid (ice) to a liquid (water) takes energy. The energy is in the form of heat. The heat comes from our drink. Our drink is now cooler.

Beyond the Basics

Water usually freezes at 0 degrees Celsius. (This is 32 degrees Fahrenheit.) The temperature of ice is also 0 degrees C. You can have both ice and water at the same temperature. How is this possible?

The answer is related to very small units for measuring heat. A calorie is one such unit of heat measurement. For each gram of ice at 0 degrees C that you want to melt, you must add 80 calories of heat. If you have a gram of water at 0 degrees C, you must take away 80 calories of heat to form ice. If you add between 0 and 80 calories of heat to ice, you will have some ice and some water. The temperature of the water and the ice will be 0 degrees Celsius.

Something to Try

Wait for a day when the temperature is about 25 to 31 degrees. Place a few crystals of salt on an ice cube. Place the ice outside. Wait several minutes. Carefully look at the ice. Do you see the holes where the ice began to melt? The heat that melted this ice came from the air. It was absorbed when the salt began to dissolve.

Something Else to Try

If you have a hydrometer, try this. Place some water in a container. In another container mix several spoonfuls of salt with about a half a pint of water. Use the hydrometer to test the freezing point of each liquid. You should find that the salt water has a lower freezing point than the fresh water.

The freezing point of water (and most other liquids) is lowered when another substance is dissolved in it. The amount of lowering is determined by the properties of the liquid. The material put into the liquid also helps to determine the amount of lowering. The relative amounts of the two materials is also a factor. The more "stuff" you dissolve in a liquid, the lower the freezing point will be. This works because the dissolved material interferes with the crystal formation of the liquid.

Here is an interesting question. Since salt lowers the freezing point of water, why don't we put salt in our car's radiator? Clue: What does salt do to the body of a car?

Physical Science: Lesson 13

Are You Wet?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of a cycle in nature.

√ emphasize the importance of good water management.

√ explain the wide variety of uses for clean water.

For Class Discussion:

√ Where do towns and cities generally drain their sewage? Where do towns and cities generally get their drinking water?

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 467-471)

R. Oram, *Biology: Living Systems* (Teacher's Edition), Charles E. Merrill, Columbus, OH, 1979. (569-570)

Physical Science: Lesson 13

Are You Wet?

Science Concepts:
Water Facts
Water Cycle

Water is a very important liquid. It is so important many books discuss it separately from the other liquids found in the world. You use water in some form during each day of your life. There are many facts and concepts about water. Lets look at some of them now.

There is a lot of water in the world. One estimate says that the Earth has about 326 *million* cubic miles of water. That is a lot of water! It would be similar to a box with a width of over 688 miles, a length of over 688 miles, and a height of over 688 miles. Most of this water is in the oceans. About 97% of the Earth's water is in the oceans. Less than 0.001% is in the air. A little over 2% is in the form of ice and glaciers. Fresh water lakes have only 0.009% of the Earth's water. Rivers have even less than lakes. This may help you to understand why some scientists are concerned about the pollution in the ocean.

The Earth's water circulates. Rain from clouds goes into rivers, lakes, ground water, etc. Some of this water evaporates back into the clouds. Some of the water finds it way into the oceans. A lot of ocean water evaporates each day to form new clouds. The clouds cool and cause rain or snow. This endless cycle is called the water cycle.

A given drop of water could move through the complete cycle (lake, cloud and back to lake) in a few days. Or, a drop of water could get trapped in a glacier for 40 years. Some water deep underground may have been there for 10,000 years. It takes a lot of energy to move this water through the cycle. Some scientists say that the hydrologic cycle uses more energy in a day than has been created by people in all of history. Where does all of this energy come from? The sun. Heat energy from the sun is used to evaporate water. This keeps the cycle moving.

Water is a very important liquid for living things. Neither plants nor animals could live without water. Water is as important as food. In fact, you would die of thirst before you would die of starvation. About 65% of your body's weight is water. If you weigh 150 pounds, about 98 of those pounds are water.

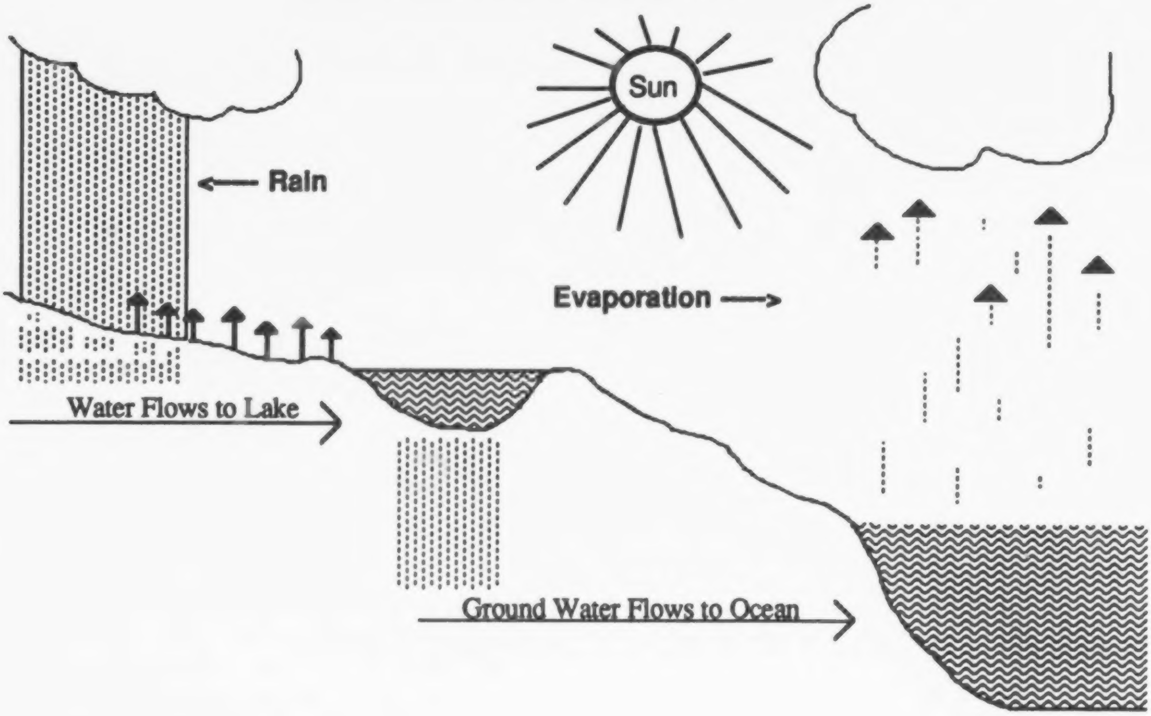


Figure 13.1 Water cycle

Besides being needed in living things, water is important for a lot of other reasons. Throughout history water power was used to do work. As early as 100 years B.C., people used water to help crush grain. Mills were build next to rivers so that the running water could provide energy to turn the grindstones. Later, waterwheels were built to "capture" energy for factories. In the year 1086 England had about one water mill for each 400 people. Later, water power was used to saw wood, spin silk, drive pumps, and run a lot of other equipment.

We use water power to make electricity. One way to do this is by by using a dam. The water behind the dam has potential energy. When the water goes over the dam, a turbine is made to spin by the force of the water. The spinning turbine makes a generator turn. Electricity is made by the turning generator. This process changes the potential energy of the water into electrical energy.

Electricity made by water power costs less than electricity made with oil, gas, or nuclear power. It is also a very clean process. Little or no pollution is made. The problem is that there are not enough good places to make the big dams needed to trap large amounts of water.

The natural beauty of water also has a value. People love to look at oceans, lakes, and rivers. Millions of pictures are taken each year of water. Waterfalls such as Niagara Fall attract thousands of visitors each year.

Water is also important for fun. People love to use water for swimming, fishing, boating, skiing and other forms of recreation.

Water is used in industry. It can dissolve almost all inorganic substances. It is used to make other chemicals. It can cool equipment. Sometimes the industrial uses of water cause large scale pollution of our rivers, lakes or oceans.

Water can also cause disaster. Floods occur each year and cause loss of property and life. More than 2,000 people died in the 1889 flood in Johnstown, Pa. Mudslides, caused by rain, destroy millions of dollars of property.

Water is very much a part of our lives. Sometimes it causes problems, but most of the time the effects of water are good. One thing is certain. We can't live without it.

Something to Try

"A pint's a pound, the world around" is a common saying. Have you ever heard it? It is used by some people to remember how much water weighs. Lets test the accuracy of that saying.

There are several ways to do this. A couple of them will be described here. You can use the one easiest for you.

Find a small set of scales like the ones used by people who fish. They usually have a "hook" at the bottom. Punch a hole in the top of a half-gallon, paper milk carton. You can now weigh the empty carton. Remember this weight. (Because the carton weighs so little, it may show as a zero on the scales. This is okay.) Fill the carton with water. Use the scales to weigh the half-gallon of water. Subtract the weight of the carton. This gives you the weight of a half-gallon of water. You will have to divide this weight by four, since there are four pints in a half-gallon. This will be the weight of one pint of water. Did you find it to be one pound?

If you have scales in your bathroom, you may be able to use them as follows. First, weigh yourself with an empty container such as a bucket. Next, put exactly two gallons of water into the bucket. Hold the bucket of water and get on the scales. This is your weight plus the bucket plus the water. From this number, subtract the weight of you and the empty bucket. This is the weight of two gallons of water. Divide this number by 16. (There are 16 pints in two gallons.) Your answer will be the weight of one pint. Did you find it to be one pound?

If everything worked correctly, you should find the weight of one pint of water to be about one pound. To be exact the weight of one pint of water is 1.04 pounds. It seems that the saying, "A pint's a pound, the world around" is correct.

Something Else to Try

How much does the water that goes into a waterbed weigh? To answer this question you must know how many gallons of water will be put into the bed. You must also know how much water weighs.

From the above activity, we know that a pint of water weighs 1.04 pounds. A gallon must weigh eight times that amount. Eight times 1.04 is 8.33 pounds per gallon. We will multiply this number (8.33) times the number of gallons of water in the bed.

As an example, lets say that the bed needs 40 gallons of water. We would multiply this by the weight of one gallon of water. Our answer would be about 333 pounds of water for that bed. (40 Gal. times 8.33 Lbs.)

To do a real example you must find someone who has a waterbed and ask him/her how much water goes into the bed. You could get this information from a furniture store that sells waterbeds.

Physical Science: Lesson 14

Moving on Up

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of an inclined plane as one of the simple machines.

√ emphasize the difference between effort and work.

√ explain the relationship between a screw and an inclined plane.

For Class Discussion:

√ Discuss some common uses of an inclined plane.

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 134-135)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (pages 102-105)

Physical Science: Lesson 14

Moving on Up

Science Concepts:

Friction

Inclined Plane

One of the oldest machines in the world was not invented by humans. It exists in nature. This machine was probably used by ancient animals long before people were on Earth. It was later used by the Egyptians to build pyramids. It gave someone the concept needed to invent the screw. Which of nature's machines do you think is being described?

If you guessed a "hill," you are right. But when we describe a hill as a machine, we call it an inclined plane. It does not matter what you call it. Both a hill and an inclined plane demonstrate the same science concepts. Both can help us to do work.

Before we look more closely at an inclined plane, it is important to talk about the meaning of a few words. When machines are being described, you will often see the word, "easier" being used.

For example, people say that an inclined plane can make our work *easier*. Or, you may read that a movable pulley can make our work *easier*.

What do science books mean when they use the word easier? Do they mean that we can do the job with less total effort? Definitely not. They usually mean that the job can be done with less effort at any given moment. But since the job may take longer, the total effort will be the same. In fact, there are times when the use of a machine will *increase* the *total* effort needed to do the job. (Friction would be one reason for this increase.)

The definition of work is the movement of an object through some distance. It takes effort (energy) to move that object. You can use a lot of effort for a short time to do work. Or, you could use less effort over a longer time to do the same work. Either way, your total work will be similar.

For example, you could throw a box 10 feet. Or you could drag that same box for10 feet. In the first case there was a lot of effort for a very short time. In the second case the effort was less. But that effort was done over a longer period of time. The total work done (moving a box 10 feet) was the same.

Suppose that we want to move a box to the top of a loading platform. If we have enough strength, we could just lift the box. But suppose that the box is too heavy to lift. Then we could use an incline plane (hill) to help us do the job.

Look at Figure 14.1. You can see that box "A" would only have to be moved five feet to get to the top of the platform. Box "B" would have to be moved 10 feet.

If you were to lift box "A," it would take 50 pounds of effort, times the distance of five feet. This would be a total of 250 foot-pounds of effort. Notice that the incline plane will help you hold the weight of the box. So you may only have to use 25 pounds of effort to move box "B." Your total work would be 25 pounds of effort time10 feet. That is also 250 foot-pounds of effort. Both methods take the same total amount of energy. But in non-scientific words, the work was "easier" when the inclined plane was used.

We use inclined planes every day. A stairway is an example of an inclined plane. Without a stairway in a two-floor house, it would be difficult to get from the lower level to the upper level. The work being done is that of lifting our body through a distance. The steeper the staircase, the less benefit we receive from the inclined plane.

There are several different types of inclined planes. Two types of inclined planes have special names. They are the screw and the wedge.

The screw is a special case of an inclined plane. There are several ways that we use the idea of a screw. You could think of a wood screw as nothing more than an inclined plane wrapped around a nail. A spiral staircase is also an example of a screw. Some automobile jacks use the concept of a screw. The propellers of boats and airplanes are screws.

The mechanical advantage of a screw depends on the pitch of the screw. The steeper the pitch, the greater is the force needed to use the screw to do work. This is why some power boats and airplanes can change the pitch of their propeller. Changing the pitch of a propeller, is like shifting gears in a car or truck.

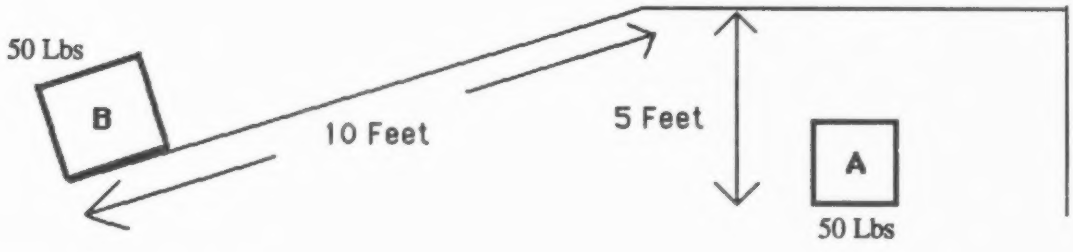


Figure 14.1 Inclined plane.

A wedge is nothing more than two inclined planes placed back to back. A wedge makes it easier for an object to move through another object. Examples of wedges include knives, axes, nails and wood splitters. The idea of a wedge is used in streamlining vehicles. Anything that looks "arrow shaped" has the concept of a wedge.

Because of friction, the advantage of a wedge is very difficult to calculate. But the longer and thiner a wedge is, the greater will be its mechanical advantage.

A Little Bit More

If you did an experiment to measure the work needed to move each of the two boxes in Figure 14.1, you may be surprised. You would probably find that it takes more total work to use the inclined plane than not to use it. Why is this true?

The answer is friction. When you slide box "B" on the inclined plane, there is a lot of friction. (Friction is the resistance caused by two surfaces rubbing together.) The bottom of the box rubs on the plane. This creates extra resistance. You must use energy to overcome that resistance. There is also friction when you lift the box. The friction is from the box rubbing on the air. But when lifting box "A," the friction is so small that we can forget about it.

To make an inclined plane more efficient, it should have a smooth surface. This will reduce the friction. Another "trick" is to place something smooth under the box. A small rug can sometimes work very well. Then pull the rug.

This "rug trick" is helpful even on flat surfaces. For example, placing a throw rug under a large piece of furniture makes that item much easier to slide along the floor. It is surprising how much this can help you, especially when you are working alone.

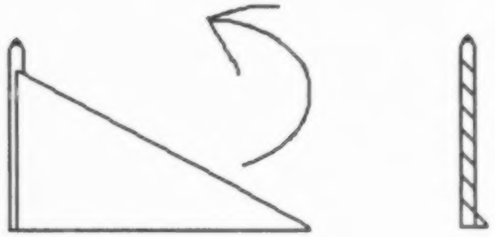


Figure 14.2 Construction of a screw

Something to Try

On a piece of paper, draw an inclined plane (right triangle) similar to the one in Figure 14.2. Cut out the inclined plane. As indicated in Figure 14.2, wrap the inclined plane around a pencil. You have just created a model of a screw.

Repeat the above activity using different shapes of inclined planes. Notice that the steepness of the plane changes the pitch of the screw.

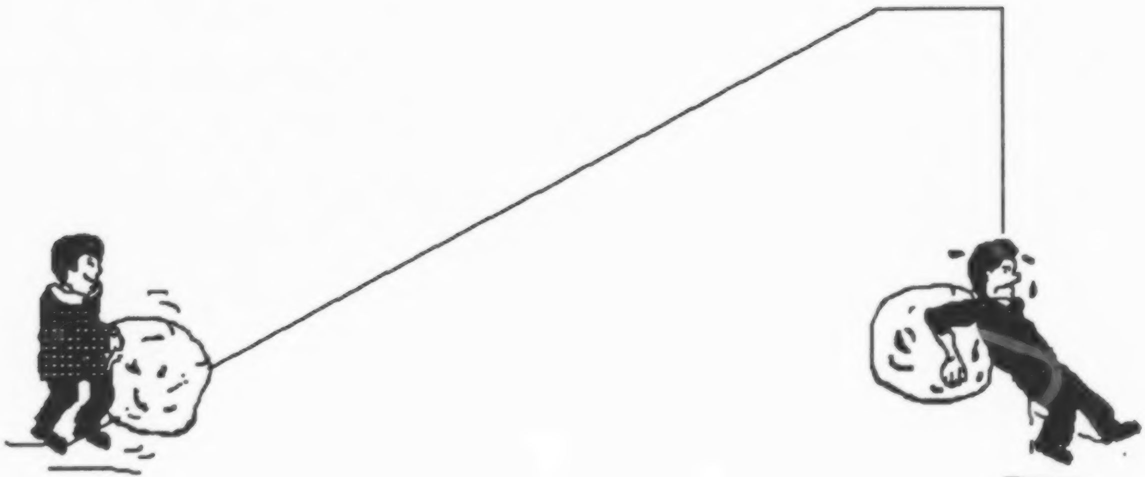


Figure 14.3 The easy way and the hard way

Karen Oravec

Physical Science: Lesson 15

Can You Lift It?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of mechanical advantage.

√ emphasize the difference between fixed and movable pulleys.

√ explain why changing the direction of a force can sometimes be very useful.

For Class Discussion:

√ If you kept adding pulleys to a block and tackle, would the mechanical advantage continue to get better? Explain your answer.

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 131-132)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (pages 96-100)

Physical Science: Lesson 15

Can You Lift It?

Science Concepts:

Pulleys
Mechanical Advantage

Several years ago there was a "party trick" that was very popular. It was often done at parties with ten or more people. To begin the trick the host would select a big man to be the "guinea pig." Then the host would try to make a bet. The bet was that the heavy man could be lifted by the smallest eight females present. Furthermore, each female could use only one finger on each hand. Often, this bet was accepted. Many people could not believe that the heavy man could be lifted by using just two fingers of each woman.

Who do you think won the bet? If you guessed that the host won most of the time, you are correct. Was there a trick? No, not a trick. Just an understanding of science.

Lets examine how eight people could each use just two fingers to lift a heavy man.

Begin by saying that the man weighed 192 pounds. Each person used two fingers (one from each hand). That would be a total of 16 fingers. If we divide the man's weight by the number of fingers, we find how much each finger must lift. That would be192 divided by 16. The answer is 12 pounds. Now we see that each finger only had to lift 12 pounds. That isn't very much. That is why the host usually won the bet.

But how does that party trick relate to science? As you will see by the end of this lesson, it relates to the idea of a block and tackle and other forms of pulleys.

A pulley is a grooved wheel supported in a frame (Figures 15.1 and 15.2). A simple block and tackle is just a fixed pulley connected to a movable pulley (Figure 15.3). The number of pulleys in a block and tackle can vary.

These simple machines can help you do work. When you do work, you use effort to move something. Your effort is in the form of a force pulling on the rope. A pulley can make your job easier in two ways. It can change the direction of your effort. For example, a pulley could allow you to pull down instead of up. This could make the task easier. A fixed pulley can also reduce the effort that you must use at any given time. This reduction is called a mechanical advantage. This advantage does not reduce the total energy needed to do the job. We will discuss both of these ideas in more detail.

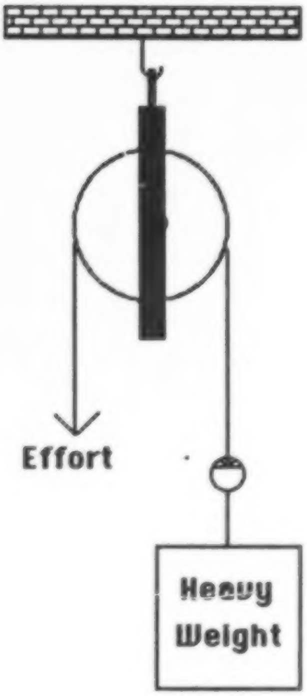


Figure 15.1 Single fixed pulley.

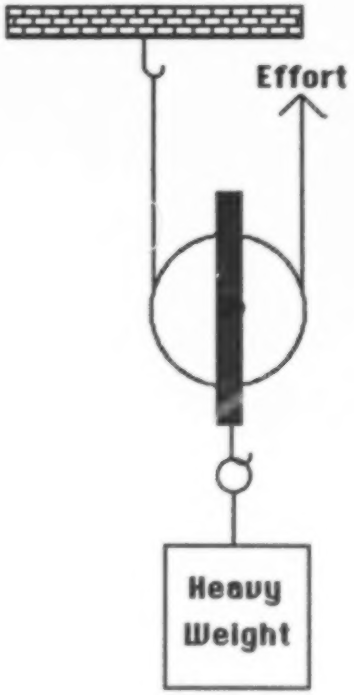


Figure 15.2 Single movable pulley.

A fixed pulley does not reduce the amount of force that you need to move an object. In other words it does not give you a mechanical advantage. But it does *change the direction* of the force. This can be very important. Suppose that it is your job to put up the flag each morning. There are several ways to put up a flag. You could get a ladder, and climb up with the flag. If you are a good athlete, you may be able to climb up the flag pole and tie the flag at the top.

These ideas are not good. Instead we use a fixed pulley. By using a pulley at the top of the pole, we can pull one end of the rope down. The flag will go up. If you pull the rope down two feet, the flag will go up two feet. Notice that you do not change the mechanical advantage. You just change the direction.

A clothes line is sometimes connected to a fixed pulley. This can allow one to hang clothes more easily. You do not have to keep lifting a heavy basket of wet clothes. You can stay in one place, and pull the rope to move the clothes. This is also useful if you live in an upstairs apartment.

An important idea to remember is that no mechanical advantage results from the use of a single fixed pulley. You do not reduce the necessary force. You do not gain speed. With a fixed pulley, you only change the direction of your effort.

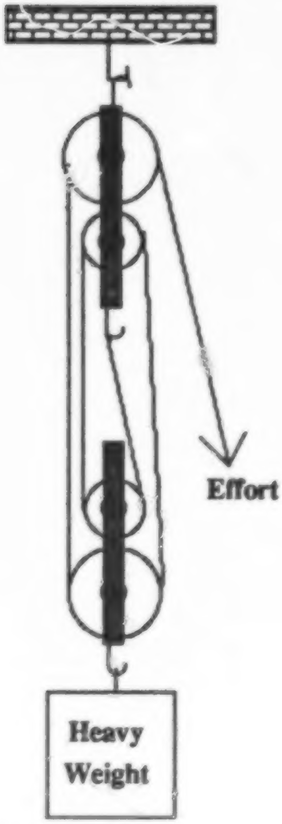


Figure 15.3 Block and tackle.

To gain a mechanical advantage we use a movable pulley (Figure 15.2). It moves when the rope moves. (You should recall that a fixed pulley does not move.) Using one movable pulley gives you a mechanical advantage of two. This means that to lift a 100 pound box, you only need 50 pounds of effort.

This is a good deal! But is there a "catch?" Yes. If you want to move the box for a distance of *three* feet, you must pull the rope for *six* feet. To reduce effort you must increase distance.

You should also notice that a single movable pulley does not change the direction of your effort. If you pull the rope up, the box moves up. You would not use a movable pulley on a flag pole. If you did, you would have to stand in the sky above the top of the pole to raise the flag!

Sometimes it is useful to connect several pulleys together. One or more pulleys in the same frame is called a *block*. When two or more blocks are connected by a rope or chain this is called a *block and tackle*. There are many different ways that you can connect pulleys together. Each different combination of fixed and movable pulleys gives different results. Connecting two or more pulleys together allows you to control the direction of your effort. This also allows you to change the amount of you effort.

If you use more ropes to support the weight, you will increase your mechanical advantage. So, if you have two ropes supporting the weight, your advantage will be two. A single movable pulley is an example of this. If you have four ropes (or chains) supporting the weight, your advantage will be four. Figure 15.3 is an example of this.

With an advantage of four, you can lift an object that weighs 400 pounds by pulling with only 100 pounds of effort. But remember, you will have to pull that rope 20 feet to make the object move five feet.

There are several excellent uses for a block and tackle. You may have seen one in use by an auto mechanic. Mechanics use a block and tackle to lift engines out of cars. Another use of a pulley system is on a sailboat. Sailors use pulleys to hoist their sails and to control the boom. A block and tackle can also be used to pull cars out of ditches and snow banks.

In fact, you can use a pulley system anytime that you want to reduce the effort of moving an object. You can also use pulleys to change the direction of your effort. So, the next time that you have a heavy object to move, think about using a pulley system to help you.

To help you remember how a movable pulley works, think of the party trick from the beginning of the lesson. Lots of small fingers can share the load and reduce the effort of any given finger. In a related way several strands of rope can share the support of an object and make it easier to lift.

A Little Bit More

There is a difference between the theoretical mechanical advantage and the actual mechanical advantage. If you have a movable pulley, the theoretical advantage is two. This is true because you have two ropes supporting the object. Hence, you could use 50 pounds of effort to lift a 100 pound object. If you set up an experiment, you would find that it would take *more* than 50 pounds to lift 100 pounds.

Why would that be true? The answer is friction. As the pulley turns, it rubs on its axle. This causes friction. There can also be friction between the rope and the frame of the pulley. To reduce the friction you should keep your pulleys lubricated. You should also use the correct thickness of rope or chain.

Physical Science: Lesson 16

Three of a Kind

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of a lever.

√ emphasize the usefulness of levers in our everyday world.

√ explain the differences between the three classes of levers.

For Class Discussion:

√ If you were to build a tall building, could you do it without any form of lever. Discuss your answer with others in your class.

For More Information:

C. Heimler, *Principles of Science, Book One,* Charles E. Merrill, Columbus, OH, 1979. (pages 126-127)

J. M. Pasachoff *et. al., Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 100)

Physical Science: Lesson 16

Three of a Kind

Science Concept:

Levers

The Great Pyramid at Giza was built almost 5000 years ago. It is in Egypt, and it was used as a tomb for a king. Of course it is also a monument to that same king. The ancient kings believed that their dead bodies must be in perfect condition for success in the next life. When a king was buried in a pyramid, lots of food and other necessities were buried with him. These things were carefully hidden in the pyramid, and the passages were blocked to keep robbers out.

Pyramids are so big that modern scientists wonder how the Egyptians were able to build them. The Great Pyramid is about as tall as a 50 story building. It is built on almost 14 acres of land. One estimate is that the Great Pyramid is made from 2,300,000 stone blocks. These huge blocks of stone weigh over two tons each. Some of the stones are 18 feet wide and over 7 feet tall.

It must have taken a long time to build a pyramid. Some say that it took about 100,000 people over 20 years to build the Great Pyramid. And they did it without modern equipment. They had no trucks to haul the stone. They had no cranes to lift the blocks into place. They had no power tools to cut the stones. What machines did they have?

Nobody knows for sure. But many people who have studied the pyramids, believe that they used simple machines. Very long inclined planes may have been built as "roads" to the top of the pyramid. Another theory is that levers were used to lift the huge blocks to the top of the pyramid. How could a lever be used to lift a 2-ton rock to the top of a 50-story building?

Do not under estimate the power of a lever. There was an ancient Greek scientist whose name was Archimedes. He once said that he could move the world if given a lever that was long enough. Of course he would need a place to stand in the sky. He would also need a fulcrum for his long lever.

But Archimedes's statement was to make a point about the power of levers. It was not something that was useful in the real world. How could a lever help to lift the blocks that make up the Great Pyramid?

Maybe this was done by the use of load arms. A load arm is a large lever similar to the device in Figure 16.1. A tree trunk could be used as the main part of the lever. This lever would rest on a strong fulcrum (pivot point). The short arm of the lever would be directly over a large stone. A sling from the short arm of the lever would go around the stone. Many smaller rocks are piled on the other end of the lever. At some point the large rock would lift up. It might only go up two feet. The exact height would depend on the size of the lever and the position of the fulcrum.

Sand could then be placed under the rock. The sling could be taken off the rock. The load arm itself would be lifted by the workers. Sand would be placed under the raised machine. Now from a higher height, the entire process would be repeated. If several of these lever-machines were in use at the same time, many stones could be lifted.

Later we will look at many different ways that we use levers today. But first, lets look more closely at the machine known as a lever. There are only two main parts to a lever. The arm and the fulcrum. The arm is the long stick-like part. The fulcrum is anything that can be used as the pivot point. Unless the fulcrum is exactly in the middle of the arm, you will have a short length and a long length of the arm. The object that you are trying to move with the lever is called the resistance. The energy used to move the lever is called the effort.

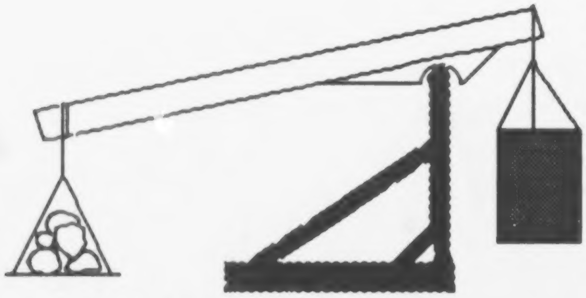
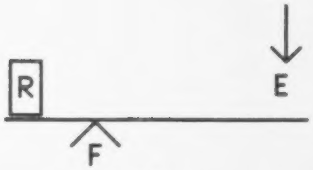


Figure 16.1 Diagram of a load arm

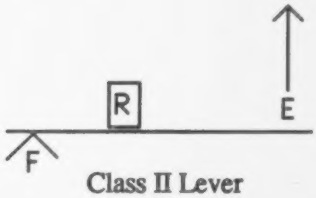
The distance from the effort to the fulcrum is called the effort arm. The distance from the resistance to the fulcrum is called the resistance arm.

By placing the fulcrum in different positions, you can change the nature of the lever. There are three classes of levers. These are shown in Figure 16.2. A first class lever has the fulcrum under the mid-portion of the arm between the effort and resistance. A second class lever has the fulcrum under it, but the resistance is between the effort and the fulcrum. In a third class lever the effort is between the fulcrum and and the resistance. Each of the three classes of levers has different uses.

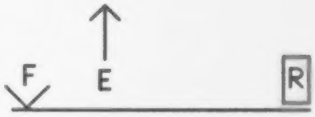
Class one levers can be used to change the direction of your effort. That is, you can push down and the resistance will go up. You can change the advantage of the lever by changing the position of the fulcrum. The longer the effort arm of the lever, the less effort you will need to do the job. If the effort arm is longer than the resistance arm, you gain mechanical advantage. If the effort arm is shorter than the resistance arm, you loose mechanical advantage.



Class I Lever



Class II Lever



Class III Lever

Figure 16.2 Three classes of levers

Examples of class one levers include the see-saw and crow-bar. If you use a screwdriver to pry off a hub cap, you are using it as a first class lever. This is true because the fulcrum is between the effort and the resistance. You can put two class one levers together. Pliers and scissors are examples of a double lever.

Class two levers always give you a mechanical advantage. This is because the effort arm is always longer than the resistance arm. You can see why this is the case if you look again at Figure 16.2. Examples include the wheelbarrow and the nutcracker. The post-puller is another example of a class two lever.

Class three levers always have a resistance arm that is longer than the effort arm. This means that they will never give you a mechanical advantage. But we still use them because we gain distance. The broom is a good example of this. We move our arms just a little, and the bottom of the broom moves a lot. A fishing pole is another example where you gain speed and distance. You move you hands just a little, and the hook moves quickly over a distance greater than that moved by your hands. Other class three levers include baseball bats and the fly swatter. Your forearm is also an example of a class three lever. Double class three levers would include ice cube tongs, tweezers and pincers.

Beyond the Basics

You can use math to calculate the amount of effort that you will need to lift an object with a lever. The general formula is:

Resistance X Resistance Arm =
Effort X Effort Arm

Another way to state this formula is:

The effort is equal to the resistance, times the resistance arm, divided by the effort arm.

Effort = (R X RA) + EA

As an example, look at Figure 16.3. We want to lift a stone that is 250 pounds so that we can look under it for fishing worms. How much effort must we use to raise that stone?

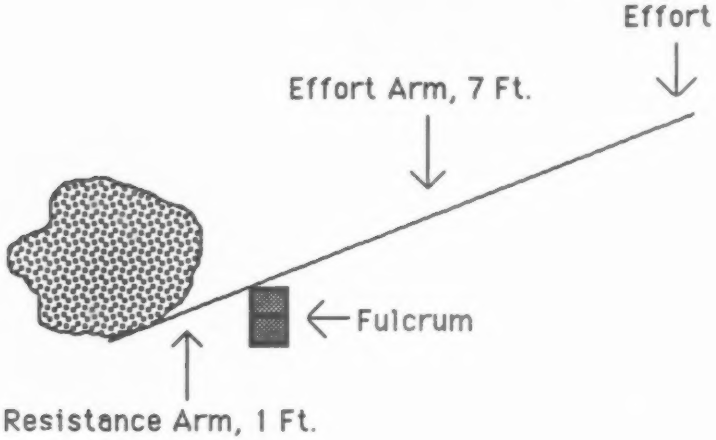


Figure 16.3 Using a lever to lift a heavy stone

Let's use a lever that is 8 feet long. (A piece of lumber such as a 2 by 4 would work.) We will put a fulcrum 1 foot from the end of the lever. We now have a class one lever. The effort arm is 7 feet. The resistance arm is 1 foot. The resistance is 250 pounds.

When we multiply the resistance of 250 times the resistance arm of 1 we get 250.

We then divide this 250 by the effort arm of 7 to get 35.7 pounds of effort. So, all we need to do is push down with an effort of about 36 pounds and the 250 pound rock will lift up. That is a nice gain in mechanical advantage.

But what we gain in mechanical advantage, we will lose in distance. If we want to lift the rock 1 foot, we will have to push down on the lever for 7 feet. Notice also that the effort is directed down, but the resistance moves up. We have changed the direction of the force.

Physical Science: Lesson 17

Where is the Big Wheel?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of the wheel and axle as one of the six simple machines.

√ emphasize the option of decreasing force or increasing speed.

√ explain the relationship between a first-class lever and the wheel and axle.

For Class Discussion:

√ If you had a screwdriver with a huge handle, would this be useful in turning down screws that a regular screwdriver could not get? Think about a possible problem with such a powerful screwdriver.

For More Information:

C. Heimler, *Principles of Science, Book One,* Charles E. Merrill, Columbus, OH, 1979. (pages 99-101)

J. M. Pasachoff *et. al., Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 99-101)

Physical Science: Lesson 17

Where is the Big Wheel?

Science Concept:

Wheel and Axle

There are a lot of big wheels in the world. Some people use the term "big wheel" as a nickname for an important person. Since there are a lot of important people in the world, there are a lot of "big wheels."

But there is another use for the term "big wheel." It is more commonly used to describe the size of a wheel on a vehicle. For example, one of the largest tricycles ever made was built in 1897. It had side wheels that were 11 feet tall. In 1968 Steve McPeak of Seattle Pacific College rode a 13-foot unicycle from Chicago to Las Vegas. His trip covered about 2,000 miles, and it took him six weeks. That same person mastered one of the tallest unicycles in the world. The wheel was 32 feet tall. That is a big wheel!

Besides being big, wheels are a very important machine. They are just as important as pulley systems, inclined planes, and levers. You may not have given it much thought, but you probably use the wheel as a machine everyday. In fact, most compound machines (those machines that use two or more simple machines) have at least one wheel. Before we look at several examples of these machines, let's see how they work.

Most wheels are used with an axle. (See Figure 17.1) Sometimes the axle is firmly attached to the wheel, and sometimes it is not. If the axle is firmly attached to the wheel, this is a wheel and axle machine. It is often called a "windlass." A door knob would be an example of this type of machine. The knob would be the wheel and the shaft would be the axle. Both the knob and the shaft turn together.

If the wheel and the axle are not firmly attached to each other, then this is not considered to be a simple machine. It would just be a wheel and an axle. A wagon wheel is an example of this. The axle does not move, but it allows the wheel to spin.

A wheel and axle machine usually has one large wheel firmly connected to a smaller wheel or axle. Both wheels will turn together. When you use a wheel and axle machine (windlass), you can gain a mechanical advantage or you can gain speed. Whether you gain speed or mechanical advantage depends on where you apply your effort.

If you apply your effort to the large wheel, you can gain mechanical advantage to a resistance on the small wheel. Again, consider the door knob. The resistance is the latch and the connecting spring. This resistance is attached to the axle. When you turn the knob, you are applying force to the large wheel. The amount of effort needed to turn the large wheel (knob) is less than the force needed to move the latch and spring on the axle.

How can this be true? How can you apply less effort than seems to be needed? It works because you exchange force for distance. You apply less force to the knob than is required to open the latch. But, you must apply this force through a greater distance than the latch must move. For example, the door latch may only need to move one-quarter of an inch to open. But to do this, you may have to move the knob a full inch. You have traded distance to gain force.

The general rule is very easy. If you want to gain force, apply the effort to the large wheel. If you want to gain distance or speed, apply the effort to the axle (small wheel). The greater the difference in size between the large wheel and the axle, the greater the gain in mechanical advantage. If you want to know how to calculate the mechanical advantage, read the next section, "Beyond the Basics."

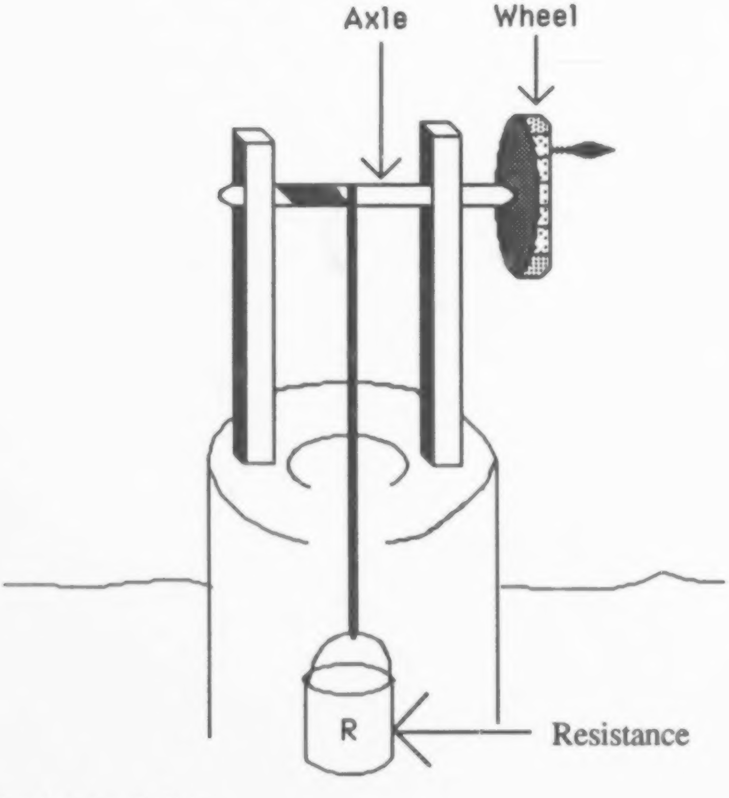


Figure 17.1 Wheel and axle windlass

There are many ways that we use the concept of a wheel and axle to help us do work. The door knob was already listed as one such example. A pencil sharpener is another example. The handle of the sharpener would be the big wheel. (It turns like a wheel.) It is connected to an axle that serves as the "grinder." The pencil goes into the grinder and becomes the resistance. If we tried to turn the axle, it would be very difficult. But we can easily turn the handle. This is because we have gained a mechanical advantage. But since the handle travels a long way compared to the axle, we have lost distance.

Another example of the wheel and axle concept is the steering wheel on a car, truck, bus, etc. If the only thing we had was the axle of the steering mechanism, most of us could not turn the car. But the steering wheel acts as a large wheel and gives us a mechanical advantage. You can demonstrate this by trying to turn the steering wheel on your vehicle by holding it at the center. This will be more difficult than if you hold the outer rim of the steering wheel.

A screwdriver is another example of the wheel and axle concept. The handle is the large wheel, and the blade (tip) is the axle. Have you noticed that as you turn a screw deeper into the wood, you must apply more effort to do the work? This is the result of increased friction. (More of the screw is in contact with the wood.) Near the end of the job, your hand sometimes slips or the screwdriver jumps out of the slot in the screw.

What do you do to get the screw to turn that last one or two turns? Some people put a thick rag around the handle. This can help for two reasons. First, it can help to keep your hands from slipping. But more important, it has the effect of making the handle of the screwdriver bigger. This will increase your mechanical advantage and make the job easier.

Another way to increase the mechanical advantage of a screwdriver, is to attach a pair of vice grips or pliers to the handle of the screwdriver. This makes the handle very large, and gives you a great increase in mechanical advantage. But be careful. You can easily snap the head off a screw using this "trick."

A Little Bit More

You can improve the wheel and axle concept by combining two or more such machines. You can connect wheel and axle systems using belts, chains or gears. A bicycle is a good example of using a chain to connect two systems.

If the bicycle has several gears, then you have many different ways that you can vary the mechanical advantage. To go up a hill select low gear. Your feet pedal very rapidly and revolve many times. But the effort at any given moment is not great. You have traded distance to gain force. When the bicycle is going down hill, you want to do the opposite. You will use high gear. Your feet pedal more slowly than they do in low gear. You lose force, but you gain speed. This is because in high gear the tires on the bike turn more often for each turn of the pedals. In low gear the tires turn less often for each turn of the pedals.

Beyond the Basics

A wheel and axle system can be thought of as a "first class" lever with the fulcrum (pivot point) at the common center. The effort arm then becomes the radius of the large wheel. The resistance arm becomes the radius of the axle. You can then calculate the mechanical advantage of a wheel and axle by dividing the radius (distance from the center to the edge) of the wheel by the radius of the axle. (The radius is the distance from the center of a circle to its edge. In Figure17.2 the radius of the axle is the distance from F to A. The radius of the wheel is the distance from F to B.)

If you are not clear on the relationship between a first-class lever and the wheel and axle, do not worry about that. The thing to remember is that mechanical advantage (MA) can be calculated as follows:

MA = Wheel Radius ÷ Axle Radius

In other words, you divide the radius of the large wheel by the radius of the axle. This number tells you how much of a mechanical advantage you have gained.

For example, assume the mechanical advantage of a screwdriver to be 4. Using 5 pounds of effort, you could turn a screw that gives about 20 pounds of resistance. But remember, you have traded distance to gain that advantage. This means that your hands must move four times further than does the screw.

If the mechanical advantage is greater than 1, you have gained force. The previous screwdriver description is an example of this. But if the mechanical advantage is less than 1, you have lost force. High gear on a bicycle could be an example of losing force to gain speed. It is possible to have a mechanical advantage of exactly 1. In which case you have gained neither force nor speed.

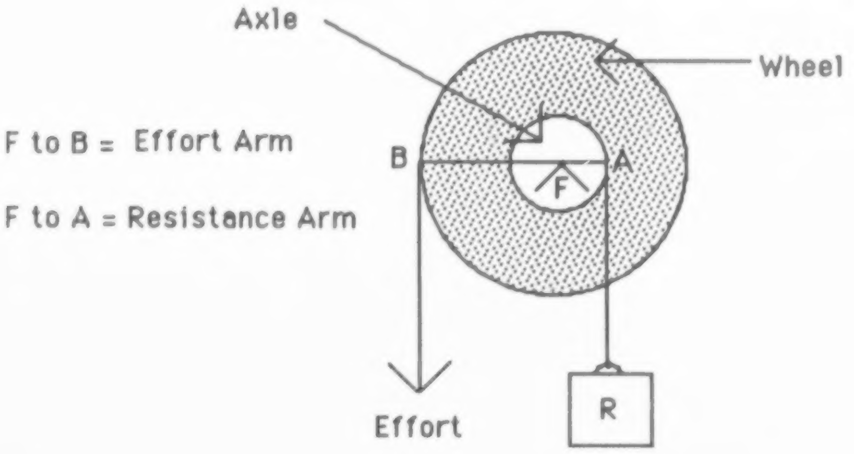


Figure 17.2 Wheel & axle as a first-class lever

Physical Science: Lesson 18

High or Low?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of air pressure in fluids.

√ emphasize the way in which atmospheric pressure operates.

√ explain why it is incorrect to say that you suck liquids through a straw.

For Class Discussion:

√ Why do large weather balloons get sent aloft without being completely filled with air?

For More Information:

C. Heimler, *Principles of Science, Book One,* Charles E. Merrill, Columbus, OH, 1979. (pages 199-243)

Physical Science: Lesson 18

High or Low?

Science Concepts:

Siphons
Barometers
Air Pressure

There is a saying that goes something like this, "You can fool some of the people all of the time; all of the people some of the time; but you can't fool all of the people all of the time." For example, a person bet that his chest and abdomen could safely withstand a force of over 3,500 pounds! How could this be possible? Was this a bet for a fool? Or was a fool making the bet?

Another interesting bet was made recently. A teacher bet a class of students that they could not have a perfect attendance record for the entire 9-week grading period. If the teacher won the bet, the students would have to do *extra* homework each night during the next marking period. If the students won the bet, the teacher would have to buy as much soda pop as each student could drink during the next marking period. The only condition was that the students must use a long straw provided by the teacher to drink the soda pop. What is the "catch?" Who made the best bet, students or teacher?

By the end of this lesson you should be able to figure out the "trick" to each of the above bets.

Before we discuss some everyday applications of air pressure, we must first examine some of the concepts that are related to air pressure. First, we must recognize that air is made up of molecules. These molecules are very tiny, but they still have some mass and take up space.

Molecules in space are not evenly distributed. Air is much more dense (thick) near the Earth's surface than it is high in the sky. We know that the atmosphere extends up at least 500 miles above Earth. But most of the air is within 20 miles of the Earth's surface. In fact, more than half of the atmosphere is within five miles of the Earth. In the early 1800s a scientist named Torricelli suggested that there were layers of air. Each layer of air was believed to press down on the layer below it. The bottom layer was at the surface of the Earth. Because of the pressure from the upper layers of the atmosphere, he named the pressure in the bottom layer, "atmospheric pressure."

Torricelli invented a device to measure that pressure. We still use it today. It is called a barometer. A barometer is a simple instrument. (see Figure 18.1) You can make a barometer by filling a deep dish with mercury. Then fill a glass tube with mercury. Next, invert the glass tube so that the open end is in the mercury that is in the dish. You now have a simple barometer. It will react to changes in the pressure of the air.

As you can see from Figure 18.1, some of the mercury in the tube is pulled down by gravity. However, gravity is also pulling down on the air. The air pressure is pushing down on the mercury in the dish, and this mercury tends to push up on the mercury that is in the tube. The higher the air pressure, the greater the force of the air on the mercury. Since the downward force of gravity remains constant, the mercury in the tube will rise as the air pressure increases.

In a sense, the tube of mercury is being pushed up by a column of air that is about 500 miles tall. At sea level, the height of a column of mercury that can be held up by air pressure is about 30 inches.

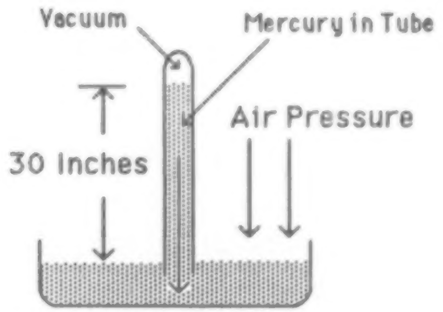


Figure 18.1 Barometer

You could use water instead of mercury to make the barometer. But since water is about 14 times *less* dense than mercury, the glass tube would have to be about 35 feet tall. That would be awkward, especially if your ceiling is only 8 feet tall.

Even a barometer made from mercury is awkward to handle. It is at least three feet tall. It must be carried and mounted and in an upright position. There is another type of barometer that does not contain any liquid. It is called an aneroid barometer. This type of barometer is based on a small, sealed box. The box has an elastic cover. Much of the air has been removed from the box, so the cover is sensitive to changes in air pressure. It moves up and down. The cover is connected to a dial using a series of levers. These levers multiply the small movements of the cover. The dial points to a scale that tells the correct atmospheric pressure. A good barometer of this type can detect very small changes in air pressure. If you move a good aneroid barometer from the table to the floor, it would register a pressure change.

Since normal air pressure can only support a column of water that is about 35 feet tall, this can cause a problem. The problem is for people who have deep wells. If you have lift pump, it will only be able to "lift" water to a height of about 35 feet. When a column of water gets taller than 35 feet, its weight is greater than the air pressure can support. Hence, the water will go no higher.

Let us think about using a straw to drink liquids. You must keep in mind that liquids are not sucked up a straw. But rather, the action of your cheeks and lips removes the air from the straw. This reduces the pressure inside the straw. The liquid is then forced (pushed) up the straw by the atmospheric pressure.

With this in mind, think about the teacher's bet described at the beginning of this lesson. If the teacher lost the bet, he/she would have to buy all of the soda pop that the students could drink through the teacher's long straw. How long do you think the teacher's straw is? It has been said that the teacher's special straw is made of rubber and is 36 feet long. A large container of soda pop would be placed on the ground. The students would have to lower the straw from the school's fourth floor window. When they try to "suck" the soda up the straw, it will not go higher than about 35 feet. That is as far up as atmospheric pressure can push water or soda pop. After that, the downward forces of gravity will be greater than the forces of atmospheric pressure. The students will not be able to drink any soda. They were tricked!

Because air pressure decreases as you increase elevation, there are some interesting things that happen on mountain tops. For example, water boils at a lower temperature. As a result, you cannot cook a hardboiled egg in the same length of time as you could at sea level. The expansion of sealed packages is another noticeable event. Most candy bars, potato chips *etc.* are packaged at relatively low elevations. The pressure inside the sealed wrapper would be equal to about 30 inches of mercury. But when you drive up a very tall mountain, the air pressure outside the bag begins to decrease. By the time you get to 12,000 feet the sealed wrapper will begin to swell like a balloon If there are no air leaks, the wrapper would eventually burst. Nose bleeds are yet another result of reduced pressure. The pressure inside of the blood vessel is great compared to the reduced pressure on the outside of the vessel. The result can be a rupture of the blood vessel.

Compared to the density of air at the Earth's surface, the density of air at 30,000 feet of elevation is relatively low. This means that there is less air resistance at a high elevation. This is one reason why most commercial jets fly at very high elevations. They can get better fuel economy, and the ride is less bumpy.

Weather reports almost always state the barometric pressure. They also talk about "highs" and "lows." As air is cooled, it becomes more dense. This creates more pressure at the surface of the Earth. The barometer will rise. We call such a situation a "high." On the other hand, air that is warming is becoming less dense. It causes a lower pressure on Earth, and is called a "low." The barometer will drop.

Large masses of air can move. When a high pressure mass of cool air moves into an area of lower pressure (warm air), a cold front is formed. This causes the warmer air to be pushed upward and cooled. When it cools, it cannot hold as much water vapor. The result is frequently rain or thunderstorms.

A warm front can also be produced. This happens when a low pressure (warm air) area moves into an area of higher pressure (cool air). The warm air tends to slip over the top of the cooler air. This tends to cool the warmer air and light rain may result. Since this situation does not cool the air as much as in the previous situation, the rain is usually lighter. But it can last longer.

A Little Bit More

A siphon is a tube that can be used to move a liquid from a higher to a lower level. This is useful when the container of liquid cannot be easily lifted or moved. A siphon is also used to draw off the upper layer of liquid without disturbing the sediment at the bottom of the tank. You may have used a siphon to take gasoline from a car's gas tank to a container on the ground.

You can think of a siphon as an upside down "J." The shorter arm of the tube would be placed in the liquid to be moved. This must be at a higher elevation than the container into which you plan to move the liquid. The longer arm would go into the container which is to "catch" the liquid.

To get a siphon started you must fill the tube with the liquid. The short arm is then placed in the liquid to be moved. The liquid will then flow up the short arm and down the long arm. To keep the siphon working, the end of the long arm must be at a lower elevation than the end of the short arm.

The siphon works because air pressure forces some of the liquid up the short arm. At the same time, air pressure is trying to force the liquid in the long arm back up that end of the tube. The liquid can't go both ways. It must flow one way or the other. Since the total weight of the liquid in the long arm weighs more than the weight of the liquid in the short arm, it flows down the long arm.

The greater the difference between the lengths of the short and long arms, the faster the liquid can flow. Since the pressure of the atmosphere is what pushes the liquid up the short arm, the short arm must be less than about 35 feet. (This assumes the liquid is water or something of similar density. The short arm would have to be even shorter, if the liquid were denser than water.)

Before we end this lesson, we must consider the man who bet that he could support 3,500 pounds of force on his chest and abdomen. How is this possible? Think about the force of air pressure. At sea level, air pressure is equal to about 14.7 pounds of force (pressure) per square inch.

Assume a man's chest and abdomen to be about 20 inches long. Assume the width to be about 12 inches. Multiplying these two numbers together, we get 240 square inches of area. This is the area on the man's chest and abdomen. Air pressure pushes down with a force of about 14.7 pounds per square inch. So the total force on the chest and abdomen is 14.7 times 240. This is 3,528 pounds of force. But why doesn't the chest get crushed? Because the pressure is equal between the inside of the body and the outside of the body. There are 3,528 pounds of force pushing out to balance the 3,528 pounds of force pushing in.

Physical Science: Lesson 19

Don't Blow Your Fuse

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of a safe electrical circuit.

√ emphasize the importance of safety while working with or using electricity.

√ explain the difference between a fuse and a circuit breaker.

For Class Discussion:

√ It is often said that extension cords can be an electrical hazzard. Do you agree? Why or why not?

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 407-433)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 383-399)

Physical Science: Lesson 19

Don't Blow Your Fuse

Science Concepts:

Fuses

Electrical Safety

The type of electricity that we have in most homes is called alternating current (AC). It is produced at an electrical generating plant and comes to you through wires. Much of the electricity that is produced never gets used. It is lost as heat during its movement through the wires. The larger the wire, the more efficiently electricity can be moved. This is why electric companies like to use large, high voltage lines to transport electricity across long distances.

Experiments are now being done that use very cold wires to transport electricity. By cold, we are talking about 200 to 459 Fahrenheit degrees below zero! When electricity moves on wires that are super cold, there is very little resistance (friction) among the electrons and the wire. So there would be almost no electricity lost during its delivery to the customers. Of course, if we ever use this concept of cold wire transmission, all of the electric lines would have to be rebuilt. The wires would have to be inside a special tube filled with something very cold like liquid nitrogen.

Once the electricity gets to your home, you can use it to do useful things. For example, you could use an electric heater and convert the electric energy into heat energy. This is how many homes are heated. You could convert the electrical energy into light energy using a light bulb. This seems simple today, but there are people still alive who remember when they had no such thing as a light bulb! You can use a radio to convert the electricity into sound energy.

Unfortunately, there are dangers related to using electricity. For example, electricity can be deadly. Many people have died from an electric shock. If you discover someone in direct contact with electricity, you must turn off the current before you touch that person. Otherwise, you may receive a deadly shock. Of course, you should call immediately for medical assistance. After the electricity is shut off, the unconscious person can sometimes be helped with CPR treatment.

One of the most common electrical problems is that of an overloaded circuit. Your house probably has several outlets connected together as a circuit. The amount of electricity that can safely travel along the wire is determined by the size of the wire. A thick wire can hold more current than a thin wire. But note the way wires are rated. The thicker the wire, the smaller its rating number. So, a 10 gauge wire can carry *more* current than a 14 gauge wire.

A circuit is rated by the number of amps of current that can travel on that wire without causing an overload. If you plug in too many appliances, you will cause too much current to travel over the wire, and it will overheat. When a wire overheats, it gets red hot and melts or burns its insulation. This can cause a fire in your building. (Later in this lesson you will learn how to tell if there is an overload on a circuit.)

To prevent circuits from overheating we use fuses or circuit breakers. A fuse is an intentional weak link in the circuit. It is designed to melt when the current gets too high. When it melts, the circuit is broken and the electricity stops flowing in that circuit. This prevents the wires from overheating and starting a fire. After the overload has been corrected, the fuse can be replaced or the circuit breaker can be reset.

Sometimes you hear about people who replace their fuses with a penny or other small piece of metal. This should not be done. It is dangerous for two reasons. First, you could get a shock placing the penny in the fuse box. Second, if that circuit becomes overloaded, the wires will get red hot and this could start a fire.

Another very important point is the size (rating) of the fuse. Fuses are rated in amps. For example, 15 amps is a common rating for a fuse. This rating must not be greater than the rating for the wire in the circuit. For example, if the wire in a circuit can carry 20 amps, then the fuse must be rated at 20 amps or less. Never more.

Do not mix up the size of the wire with its ability to carry a certain amount of current. For example, 18 gauge wire cannot safely carry 18 amps of current. On the other hand, 10 gauge wire can carry more than 10 amps of current. In other words, the size of the wire is not the same as its rating to carry electricity.

Another type of safety device is called a circuit breaker. It has the same purpose as a fuse. But it works differently. It uses a magnet to shut of the current if the circuit gets overloaded. A circuit breaker is usually reset, not replaced, after it opens the circuit.

Short circuits are another hazard. A short circuit occurs when the main flow of electricity does not go through the intended location. A common example is when two bare wires of a pair touch each other. This sometimes happens when people put extension cords under carpets. Over a period of time the internal insulation gets worn away and the two wires make contact. The electrical current will jump directly from one wire to the other. Huge amounts of electricity will flow through the circuit making its wires immediately hot. Sparks will probably fly. You may smell smoke. The fuse or circuit breaker should open the circuit to shut off the current. That extension cord should be thrown away, not fixed, because it may have worn places that you cannot see.

Beyond the Basics

In this section you will learn how many appliances can be plugged safely into one circuit. To do this, you must be able to do addition, multiplication and long division.

First, it should be emphasized that it is not necessarily the number of appliances on a circuit that cause it to become overloaded. It is the number of amps of current being used by those appliances that really matters. For example, you may be able to safely put 20 small light bulbs on one circuit. But you could not safely put three electric room heaters on one circuit. This is because the light bulbs do not need very many amperes, but the heaters do need lots of amperes.

Situation:

Assume that a circuit has 12 wall outlets. This circuit is rated at 20 amperes. It has a 20 ampere fuse. Furthermore, that circuit has a TV, stereo, and four light bulbs connected to it. How many amperes are on that circuit? You do not have enough information to solve this problem. Lets work through it together.

Solution:

We know that the circuit is rated as 20 amperes. We cannot safely go above this number. But we do not know the number of amps being used by the TV, stereo, and four light bulbs. Once we know how many amperes are already being used, we can calculate whether or not we can safely plug the heater into that circuit.

To find out how many amperes an appliance uses, you should look carefully for a label on the bottom or on the back of the appliance. This label may tell the exact number of amperes used by that appliance. (Sometimes you will see the abbreviation "A" or "Amp" used in place of amperes.) If you find the number of amperes, write that number down. Then go to the next appliance and look for its label.

If everything on the circuit has a label with the number of amperes listed, simply add up the total number of amperes. This tells you how many amperes are being required for that circuit. For reasons of safety, that number should always be less than the ampere rating of the circuit.

But what if the number of amperes is not on the label? What happens if there is no label? Then how do you know its ampere rating?

A light bulb is a good example of something that will not have an ampere rating. But it will have a wattage rating. In a case like this you can divide the number of watts by110. This will give you the amperes used by that device. For example, if a light bulb is rated at 100 watts, it uses 0.9 amperes (100 divided by 110 = 0.9).

How can you tell the amperes or watts of an appliance if there is no marking or power rating on the appliance? Then you could estimate its rating from a list similar to the following table. Your electric utility company can probably supply you with a more detailed table.

Device	Ampere
B&W TV	0.5
Color TV	2.3
40 Watt Bulb	0.36
100 Watt Bulb	0.91
250 Watt Bulb	2.27
Refrigerator	5.6
Hair dryer	10.9
Computer	1.0
Radio	0.8
Toaster	13.6
Microwave	11.5

In the situation listed previously, there was a TV, stereo, and 4 light bulbs on one circuit. If the TV uses 2.5 amperes, the stereo uses 1.8 amperes, and each light bulb uses 0.9 amperes (3.6 for the four bulbs), the total amperes on that circuit would be 7.9 (2.5 + 1.8 + 0.9 + 0.9 + 0.9 + 0.9).

Since the circuit was rated at 20 amps, it could still handle an additional 12.1 amperes (20 - 7.9 = 12.1).

Notice that we never used the information about the12 outlets. The number of electrical outlets is not a factor in these calculations.

Something to Try

Identify one or more electrical circuit(s) in your home. Unless you have a wiring diagram, this could take a little while. One way to identify the outlets on a given circuit is to plug a radio into an outlet. Turn the volume up high on the radio. Then go to the fuse box and unscrew one fuse at a time until you find the one that causes the radio to shut off. You could use a lamp instead of a radio, but then you would have to keep running back and forth between the fuse box and the outlet.

Once you have found which outlets are on a circuit, add up the amperes that are on that circuit. If that number is larger than the fuse rating, you may want to remove some of the appliances from that circuit. Otherwise, a fuse will blow if all of those electrical items are in use at the same time.

Physical Science: Lesson 20

A Shocking Experience

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of a storage cell for electricity.

√ emphasize the improvements in batteries over the years.

√ explain how static electricity is different from AC or DC electricity.

For Class Discussion:

√ You may have heard the expression, "lightning never strikes twice in the same place." Do you agree with that expression? Why or why not?

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 407-433)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 383-399)

Physical Science: Lesson 20

A Shocking Experience

Science Concepts:

Wet Cell
Dry Cell
Static Electricity

One of the most "shocking" experiments ever done was in the year 1752. This is when Benjamin Franklin is believed to have done his famous "kite and key" experiment. In this experiment he connected a piece of metal (probably a key) to the end of a kite string. He also tied a piece of silk cloth to that end of the string. The other end of the string was tied to a kite. During a thunderstorm, he flew the kite. He did not hold the kite string in his hand. Franklin held the silk because he believed that the lightning would not travel through the dry silk. He kept the silk dry by standing under the roof of a small building. During the experiment he put his finger near the key and received an electrical shock. He was lucky that he was not injured. Several months later, Franklin's experiment was repeated by someone in France. That person was killed by the lightning!

Franklin's experiment demonstrated several things. First, he showed that lightning was electricity. Second, he demonstrated that electricity can travel through a wet string.

To fully understand the importance of his experiment you must remember what life was like in the 1700s. Many people in Franklin's time thought that lightning was a mysterious event. That belief probably goes back to the time of the ancient Romans. They believed that lightning was a fire being thrown at a sinner by an angry god in the sky. In Franklin's time there was no electricity for people to use. Of course, there were no radios, no hair dryers, no VCRs, no computers, no electric lights, no movies, and no TV sets.

We have learned a lot about electricity since Franklin's experiment in 1752. Let's take a look at a few of the topics that are related to direct current and static electricity.

Batteries:

Several years after Franklin's experiment, an Italian scientist named Volta invented a device that would produce electricity. He called his device a voltaic cell. A voltaic cell produces electricity by changing chemical energy to electrical energy.

To understand how this can happen you must know that electricity is nothing

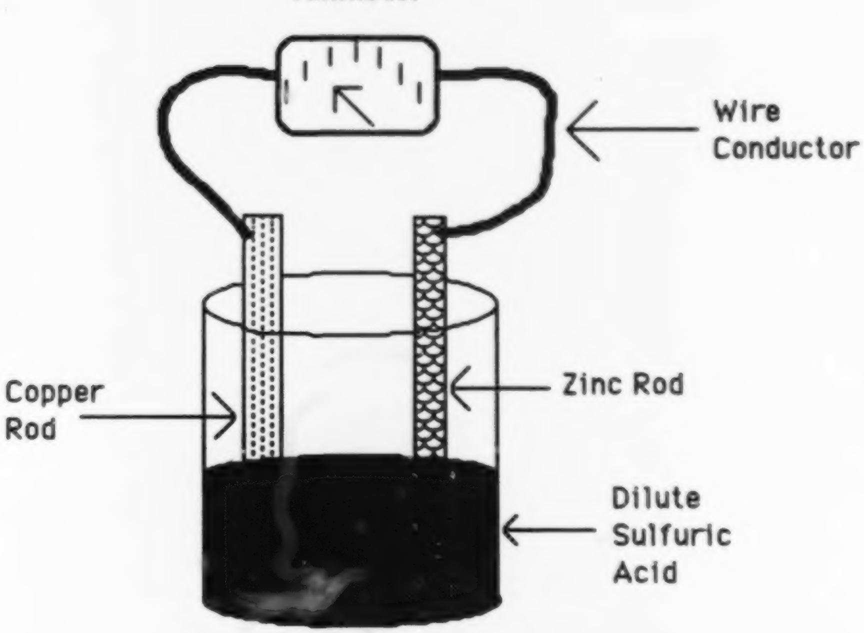


Figure 20.1 A wet cell with ammeter

more than electrons moving from one place to another. Electrons are super-tiny parts of an atom and cannot be seen with your eye. Electrons can be detected with instruments. Electrons have a negative charge and travel on a conductor. A conductor can be anything through which electrons can move. Wire is a common conductor. Conductors can also be wet string, rope, tree branches and even your body.

A typical voltaic cell is a glass container filled with an acid. Two different metals, in the form of rods, are placed into the acid. The top of each rod is above the acid. The top of the two rods are connected by a conductor. (Figure 20.1)

An ammeter is an instrument that measures electrical current. If you connect an ammeter between the two metal rods, you can measure the amount of current that is moving on the wire. You can show that different combinations of metals produce different amounts of current. You can also show that the amount of current is related to the type and the strength of the acid. The metal rods can be made from several different metals. Zinc and copper are often used. Dilute sulfuric acid can be used as the acid in the voltaic cell. Two or more cells connected together are called a battery.

The chemical reactions in a voltaic cell are easy to summarize. As the zinc rod dissolves in the acid, electrons are released. Lots of these electrons collect near the zinc rod. The copper rod gives up electrons and becomes positively charged. The electrons (negative charge) near the zinc rod move on the wire to the copper rod which has a positive charge. This movement of electrons on a conductor is electricity. In this type of movement the electrons are moving in one direction from the zinc to the copper. This one-direction movement of electrons is called direct current (DC).

Because there is liquid (acid) in a voltaic cell, it is called a "wet cell." As you can imagine, a wet cell is not very safe to move around. That is why the "dry cell" was invented. A dry cell uses a moist paste instead of a liquid acid. The container of a dry cell is often made from zinc. (This takes the place of one rod in the wet cell.) The dry cell has a carbon rod down the center. (This takes the place of the copper rod in the wet cell.)

The zinc container is not covered at the bottom of the dry cell. This is the negative end of the cell. The electrons collect at this point. The carbon rod gives up electrons and has a positive charge. The tip of this rod is the "bump" at the top of a dry cell. This bump is called the positive end of the dry cell.

When someone connects the positive carbon rod (top of the dry cell) to the negative zinc container (bottom of the dry cell) electrons will move. This electricity can ring bells, create a light in a bulb, make small DC electric motors run, etc. Remember that this is direct current; the electrons move in only one direction. You could not use this form of electricity to run a motor that requires alternating current (AC).

It is important to note that in recent years the dry cell has been improved. The alkaline battery is one example. This battery is advertised to last up to nine times longer than a general purpose carbon battery. Even if the alkaline battery costs two or three times more than a carbon battery, the alkaline battery would be a better buy.

Static Electricity:

Have you ever seen a chain dragging underneath the frame of an oil or gas tanker truck? Have you ever noticed how silk clothing sometimes clings to a person? Have you ever received a shock from touching a door knob or another person? What do all of these things have in common? Static electricity.

Static electricity is different from current electricity such as AC or DC. Static electricity builds up on the surface of materials and tends to stay there. This form of electricity is not generally used to help us do any work. In fact, static electricity is usually a nuisance.

Before we can understand how static electricity is made, we need to think briefly about molecules and atoms. You may already know that all things are made from molecules. Molecules are the smallest part of matter that still have the chemical properties of that substance. For example, a molecule of water could be identified as "water." But if we break apart a molecule into its atoms, those atoms could not be identified as "water."

Atoms are made from protons, neutrons, and electrons. The electrons have a negative electrical charge. The protons have a positive electrical charge. (The neutrons are neutral and have no net charge.) Atoms can gain or lose electrons and protons. When this happens, the atom's charge can change. If an atom gains electrons, it becomes more negative. There is another way for an atom to become more negative. It can loose protons. By loosing positive charges (protons), an atom becomes more negative. An atom can be neutral, positive or negative with respect to its overall electrical charge. This is determined by the number of electrons and protons that the atom has.

A basic law of electricity is that particles with different charges attract each other. Particles with the same charge repel each other. When silk rubs against other objects, the silk collects electrons and become negatively charged. It will then attract any object (including a person) that has a positive charge on its surface.

There are several ways to reduce the problems created by static electricity. Adding moisture to the air is one example. This can be done with a humidifier. The water molecules in the air will allow the static electricity to drain from the surface of the object. Now you know why static electricity is common on dry days, but seldom present on humid days.

To reduce static in a clothes dryer some people buy special cloths. You throw these cloths into the dryer along with the clothes. The special cloth works to neutralize the electrical charge on the clothes so that things do not cling together.

Static electricity can be a serious problem for the delicate chips in a computer. If you have a static charge on your body when you touch a computer, you can "blow" a chip. The solution is to discharge yourself before you touch the computer. You can generally do this by touching a metal chair, water pipe, radiator, door knob, etc just before you touch the computer.

When a truck is in motion, some of its parts rub on other parts. This can create static electricity. This static could discharge and make a spark. This would be dangerous if the truck has a load of gasoline. In an effort to safely discharge the static electricity, some trucks drag a chain. This is to allow the static a chance to drain safely to the ground before a spark is created.

Physical Science: Lesson 21

Speed It Up

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concepts of speed, motion, momentum and acceleration.

√ emphasize the three laws of motion and their application to the everyday world.

√ explain how speed and velocity are different.

For Class Discussion:

√ What happens when two moving objects (cars or people, for example) of different sizes run into each other? Discuss your response in terms of momentum.

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 104-124)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 39-54)

Physical Science: Lesson 21

Speed It Up

Science Concepts:

Speed
Motion
Momentum
Acceleration

The concept of motion is related to many of the things that we do everyday. Laws of motion describe how a car accelerates, why bowling pins get knocked down, why a rotary lawn sprinkler works, why seatbelts are used, why the largest football players usually do not play in the backfield, *etc.*

In some places the sport of slow-pitch softball is very popular with both men and women. In fact, more adults play softball than baseball. Did you ever notice that the softball field is significantly smaller than the baseball field? The outfield fence of a softball diamond is closer to home plate than is the fence of a baseball diamond. Does this guarantee more home runs in a softball game? Probably not. If you do not already know, later in this lesson you will learn the scientific reason why the softball field is smaller than the baseball field.

Motion and Speed

Motion is a continuing change of position. As you walk across the room, you are constantly changing your position. Hence you are in motion. The rate of motion is called speed. The speed of a running person is higher than the speed of that same person when he/she is walking.

The first law of motion states that objects tend to remain at rest unless acted upon by a force. It is also true that objects tend to remain in motion unless acted upon by a force. For example, assume that you are sitting in the front seat of a car that is moving. What happens to you when the car makes a sudden stop? Unless you are well prepared for the stop, you will lunge forward. This is because your body is in motion, and it wants to continue in motion. What was the force that stopped the car? Hopefully it was the brake system of the car, but it could have been a big tree or other object.

The tendency of an object to keep its present state of motion is called inertia. Thus in the above example, it was your inertia that tried to keep you going when the car came to a stop. Sometimes inertia can be a big problem. In some cases we can overcome the problem of inertia. Seatbelts are one way to help overcome the danger associated with speed, inertia and quick stops.

In the United States speed is usually measured in miles per hour. For example, the current speed limit on most highways is 55 miles per hour (MPH). Other units such as feet per second or meters per second can also be used to measure speed. Cars use a device called a speedometer to measure speed. This is different from the device called an odometer that measures distance. It is incorrect to say, "Look at the speedometer and tell me how many miles are on that car." You can't find distance just by looking at a speedometer. You should say, "Look at the *odometer* and tell me how many miles are on that car."

When you are in a road rally, you may be interested in the *average* speed of your car. The average speed takes into account the elapsed time as well as the distance. The average speed is calculated by dividing the distance by the time.

Ave. Speed = Distance ÷ Time

For example, if you drove 110 miles in exactly 2 hours, you could calculate your average speed as follows:

Ave. Speed = 110 ÷ 2

Ave. Speed = 55 MPH

Even though your average speed is 55 miles per hour, at some points you may have been traveling slower or faster than 55. In fact, you may even have been stopped for a brief time.

Sometimes it is important to know how much time it will take to drive from one location to another. We can calculate time by using the following formula:

Time = Distance ÷ Ave. Speed

For example, you may want to know how long it will take you to drive from Philadelphia , PA to Miami, FL. From a road atlas you can see that it is about 1,239 miles between these two cities. Since the roads are good between these two cities, you decide that you could average 55 miles per hour during the time that you are actually driving. The required time would be:

Time = Distance ÷ Ave. Speed

Time = 1239 ÷ 55

Time = 22.5 hours

Of course, you would have to add the time that you plan to take for eating, sleeping, getting gas, *etc*. But your actual driving time would be about 22 and one-half hours.

Acceleration

Acceleration is a gain in speed per unit of time. This concept is very important to a drag racer. The same concept applies to all objects that increase their speed. If you are driving your car at 40 miles per hour and you press on the gas pedal, the car should accelerate. (Guess why the gas pedal is called the accelerator?)

If the car's speed is increased by the same amount each second, then we could say that the acceleration was *uniform*. Table 21.1 shows an example of uniform acceleration.

Time	Speed
end of 0 seconds	40 MPH
end of 1 second	42 MPH
end of 2 seconds	44 MPH
end of 3 seconds	46 MPH
end of 4 seconds	48 MPH

Table 21.1 Uniform acceleration

Time	Speed
end of 0 seconds	40 MPH
end of 1 second	42 MPH
end of 2 seconds	45 MPH
end of 3 seconds	47 MPH
end of 4 seconds	50 MPH

Table 21.2 Non-uniform acceleration

If the rate of change is not the same for each unit of time, the acceleration is said to be non-uniform. Cars can have non-uniform acceleration. Table 21.2 shows an example of this type of acceleration.

The most common example of uniform acceleration is the acceleration of an object that has been dropped. Objects that have been dropped are called freely falling bodies. They accelerate because of the force of gravity pulling them toward Earth.

Acceleration can be summarized by the second law of motion. It states that as the amount of force producing acceleration increases, so does the acceleration. Furthermore, the larger the mass of the object, the larger the force needed to cause acceleration. For example, drag racers use light chassis with high powered engines to gain rapid acceleration. As another example, archers use bows with a strong force of pull to provide large forces to the arrow. Finally, heavy football players generally play on the line because they often don't have the acceleration of the smaller players who are less massive.

Remember the softball and baseball discussion at the beginning of this lesson?

Do you now understand why the softball field is smaller? Think of the second law of motion. Acceleration on a larger ball (softball) will be less than on a smaller ball (baseball). Hence, the field can be smaller. If you played softball on a baseball diamond, there would seldom be a home run. This is because the force from the bat would not be great enough to accelerate a heavy softball to the fences of a baseball field. Furthermore, the force required of the human arm to throw a large softball would be too great to allow "normal" softball games to be played on a baseball field.

Momentum

All moving objects have momentum. Momentum is defined as an object's mass multiplied by its velocity. The more momentum an object has, the greater the required effort to change that object's motion. A small bullet can have large momentum because it has a very high speed. Or a very slow moving train can have large momentum because of its great mass. An object that is not moving has no momentum.

Momentum can be changed by a force acting on a moving object. The longer the force stays in contact with the object, the greater the effect on the object's momentum. This is an important concept for some athletes such as golfers, baseball players, or tennis players. In athletics this concept is called "follow through." The longer the golf club is in contact with the ball, the more the club can change the ball's momentum. This results in greater speed for the ball, hence greater distance. The same concept applies to hitting a tennis ball or a baseball.

This concept of momentum also helps to explain why light weight football players do not usually play on the interior line. Since they have a small mass, their momentum is likely to be less than players with a larger mass.

There is a law that says momentum is conserved. For example, if two moving pool balls collide, this may cause the velocities (speed and direction) of the balls to change. But if the speed of one ball increases, the speed of the other ball must decrease. Since they both have the same mass, the momentum is conserved. In a similar way the momentum from a bowling ball is transfered to one or more of the pins. The pins, in turn, can transfer some of their momentum to other pins, knocking them down.

Reactions of Motion

Newton's third law of motion states that for every force there is an equal and opposite force. Sometimes this law is stated differently. For every action there is an equal and opposite reaction. It means the same thing regardless of which wording you use.

We use this concept frequently. For example, when you turn on a rotary lawn sprinkler, it moves in one direction because water is being forced out in the other direction. If you reduce the force of the water, you can reduce the speed of the sprinkler and the distance that the water travels. Shooting a rifle is another example that demonstrates this law of motion. When you fire a rifle, the bullet shoots out in one direction. You feel a recoil (kick) in the opposite direction. These two forces are equal and opposite.

Beyond the Basics

It should be noted that the terms speed and velocity are sometimes used in place of each other. However, to a scientist, this is not correct. Speed is just a rate of motion. Velocity must also take into account the direction of the motion. Hence, you could correctly say that the car's speed is 60 miles per hour. But its velocity would be 60 miles per hour in a northeastward direction.

If a car traveled in a perfectly straight line, its average speed and its average velocity would be numerically the same. However, if the car took a zig-zag course from one location to another, its average speed and average velocity would be different. In this case the average speed would be numerically greater than the average velocity.

Something to Try

To demonstrate the third law of motion you can try the following. Connect a spring scale to the leg of a table. Connect a second spring scale to the first scale.

Pull in one direction with a constant force. Read both scales. What do you observe? You should notice that if you pulled with 8 pounds of force on one scale, there was another force of 8 pounds pulling in the other direction. This shows that when you exert a force, there are equal and opposite forces present.

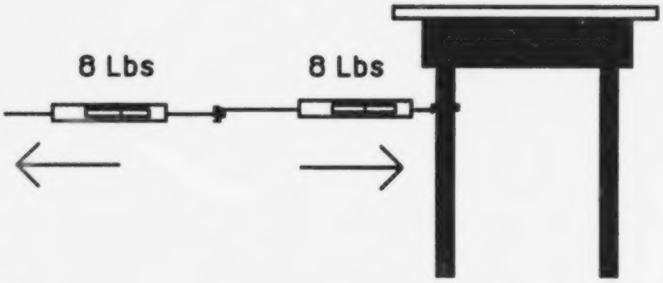


Figure 21.1 Equal and Opposite Reactions

Physical Science: Lesson 22

Falling Apples

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept of motion and gravity.
- √ emphasize the role of gravity in our everyday life.
- √ explain how a satellite stays in orbit.

For Class Discussion:

- √ What would be different if the mass of the earth were only 10% of its current mass?

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 118-120)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 73-87)

Physical Science: Lesson 22

Falling Apples

Science Concepts:

Motion

Gravity

Gravity and concepts related to motion explain many things in our lives. For example, an understanding of motion can explain how a pendulum can be used to set the time in a grandfather clock, how a spring can close a screen door, why mud flies off a moving wheel, *etc*. The reason that satellites can stay in orbit is described by laws of motion. In fact, even the success of a deer hunter can be improved by the hunter's understanding of motion.

If you want to get a good discussion going sometime, you may want to describe the following situation. This situation is especially interesting to hunters and others who enjoy guns as a hobby. Consider a hunter who has a rifle. Let us say that the hunter is on a large, flat piece of property. Furthermore, lets assume that the rifle is loaded, and that it is aimed at the horizon. The barrel of the gun is level to the ground. Lets say that the barrel of the rifle is exactly five feet above the ground. Finally, a second bullet is being held exactly five feet above the ground.

If the bullet is dropped at the same time that the gun is fired, which bullet will hit the ground first? The one that came out of the gun, or the one that was dropped from the same height as the gun? There are three possible answers. Many people will say that the *dropped* bullet will land first because it has a shorter distance to go. Others will say that the *gun's* bullet will land first because it is moving faster. Still others may say that it will be a tie. Which bullet do you think will land first? The answer will be given later in this lesson.

Gravity

You may remember the story of Sir Isaac Newton and how the falling apple inspired him to develop the law of gravitation. This law says that there is a force which pulls all objects toward each other. This force is called gravity. Furthermore, the power of this force depends on the mass of the objects as well as the distance between the objects. Objects with a small mass exert less pull than objects with a large mass. Unless the object is very massive, its gravitational force is not noticed. (By very massive, we mean millions and millions of tons.) For example, a five ton weight would attract an apple with a force less than the weight of an insect. This is why we don't notice a gravitational attraction toward a car or other such object, but we do notice the gravitational attraction toward the Earth.

The mass of the earth is estimated to be about 7,000,000,000,000,000,000,000 tons! The mass of a car would be about 1 or 2 tons. This should help show why the gravitational force between the Earth and a person is far greater than the gravitational force between a car and a person.

It is useful to realize that acceleration due to gravity is uniform. It has been demonstrated that in a vacuum (absence of air) all objects fall at the same uniform rate of acceleration. This rate is about 32 feet per second per second. In other words, a freely falling body will increase its speed every second by 32 feet per second. (This value will vary slightly depending on your distance to the center of the Earth.) If you drop a stone from the top of a tall building, it would accelerate (neglecting air resistance) as shown in Figure 22.1.

The speed of a falling body was measured by Galileo in the early 1600s. Prior to his experiments people did not understand the acceleration of freely falling objects. In fact, Aristotle believed that if two objects were dropped from the same height at the same time, the heavier one would hit the ground first. He may have been "tricked" by the effects of air resistance on the falling bodies. We now know that, if air resistance is neglected, all objects fall at the same rate of speed regardless of their weight.

Time	Speed
end of 0 seconds	0 Ft/Sec
end of 1 second	32 Ft/Sec
end of 2 seconds	64 Ft/Sec
end of 3 seconds	96 Ft/Sec
end of 4 seconds	128 Ft/Sec

Table 22.1 Free-falling acceleration

This acceleration of freely falling bodies explains something we already know. That is, if someone falls from a roof, he/she is more likely to be injured if the roof is 32 feet from the ground than if the roof is16 feet from the ground. But did you know that the reason for increased injury is because he/she would hit the ground with twice the speed?

Relative Motion

Assume you are on top of a tall mast of a rapidly moving sailboat. You want to drop an expensive tool to someone on the deck. You do not want the tool to go into the water and sink. Since the boat is moving forward, should you throw the tool forward? Then the boat will catch up with the tool. Or should you just drop the tool and expect it to fall straight down?

As it turns out, you should just drop the tool. Ideally, it will land at the base of the mast. This is because the tool is moving at the same speed as the boat. When you drop the tool, it will continue to move forward. It will also begin to move downward. This ideal solution ignores the force of air resistance on the tool. This force would tend to reduce the forward motion of the tool. So in reality, you would have to give the tool some forward force to counter the air resistance.

An important point about relative motion should be made. That is, when two forces are acting on an object, the forces have no direct effect on each other. For example, when you throw a baseball, it has two forces acting on it. First, your arm gives the ball a forward motion. Second, gravity gives the ball a downward motion. The result is that the ball travels in a curved path. When we throw a ball, we can compensate for the downward force of gravity. We do this by aiming the ball just a little higher than we actually want it to go. The length of time that it takes the ball to hit the ground is dependent only on the downward velocity caused by gravity.

Do you now know the correct answer to the situation at the beginning of the lesson which discussed the two bullets? Both bullets will land on the ground at the same time. This is because they both have the same downward force acting upon them.

Motion in Curves

You have probably noticed that when you go around a corner in a vehicle, you feel as though you are being pushed outward. This is because your body was going in a straight line. As your car begins to go around a curve, it changes direction. The outside door tends to push inward on you. This inward force is called centripetal force. It is necessary to keep an object moving in a curved path. The car's tires experience centripetal force from the road. This keeps the car moving in a curved path.

If the car is going too fast, the tires loose contact with the road. When this happens, there is no centripetal force pushing the car inward. The car will go straight, and possibly crash as it leaves the highway. To make the highways safer, most roads are banked at the curves. This increases the centripetal force and helps to push the cars inward as they round the corner.

Periodic Motion

Periodic motion occurs when an object moves back and forth over the same path in equal time frames. A swinging pendulum, vibrating tuning fork and a vibrating spring are all examples of periodic motion.

Of these, the pendulum is the most common example to most people. The pendulum consists of a weight (bob) suspended from a support. The support is free to swing back and forth. It is known that a pendulum takes the same amount of time for each swing. Thus, the pendulum is very useful as a regulator for clocks. The time that it takes for a pendulum to swing back and forth one time is called its period. The period can be changed by changing the length of the pendulum. Longer length pendulums have a longer period than shorter length pendulums. Hence, if you want to adjust a clock to make it run faster, you must make the pendulum shorter.

Beyond the Basics

When you go around a corner, the *apparent* pull away from the center is called centrifugal force. This outward force is a fictitious or imaginary force. There really is no force that pulls constantly away from the center. The outward force that you feel is really a straight line force that is being "forced" to go around a curve. If there were no centripetal force pushing the object inward, the moving object would not move directly outward from the center. Instead, its inertia would cause it to move in a straight line tangent to the circle (See Figure 22.1).

This tendency of objects in circular motion to fly off at a tangent is illustrated in many everyday examples. For instance, the mud flaps on a truck or a bicycle are there to "catch" the water, stones, mud *etc.* that are being thrown off the wheel. Grind stones and emery wheels in factories are equipped with special guards. This is to protect the user in the event that the wheel flies apart. The wheel could fly apart if the cohesion of its parts cannot supply enough centripetal (inward) force to hold it together.

Circular motion has many applications. It is used in washing machines to spin the water out of the clothes. As the machine spins, the water ends up on the outside edge of the circular drum. From there, the water is drained away from the machine. Circular motion is also used by amusement parks. Many thrill rides rely on centripetal force to provide the circular motion necessary for operation.

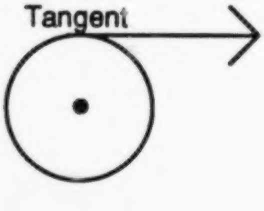


Figure 22.1 Tangent force

A centrifuge is a machine that spins very rapidly and is used in laboratories to separate chemicals with different densities (thickness). A centrifuge can also be used to separate milk from cream. This is yet another example of an application of circular motion .

Physical Science: Lesson 23

Saving Energy and Money

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept of energy conservation.
- √ emphasize conservation measures that can be done around the home.
- √ explain why fireplaces do not generally add heat to your house.

For Class Discussion:

- √ What would happen if your house was 100% air tight? Include indoor pollution as part of your discussion.

For More Information:

Physical Science: Lesson 23

Saving Energy and Money

Science Concept:

Energy Conservation

If someone came to you and offered to give you $400 a year for the next several years, would you take it? The most common answer is either "yes" or "it depends." A few people say, "no." What is your answer?

If you answered "yes," you may skip the next several paragraphs and go directly to the section labeled, "How To Do It." If you did not answer "yes," continue reading.

Those who say "no," usually say no because they do not believe that the offer can be serious. After all, who gives away money? The people who say "it depends" usually want to know if there is a catch. Some ask, "what strings are attached?"

There is a condition to the deal. You must spend $500 in the first year. But you do not have to spend additional money in any of the following years. Would you now accept the offer of $400 per year?

If you answered "yes," you may skip the next several paragraphs and go directly to the section labeled, "How To Do It." If you did not answer "yes," continue reading.

Many of the people who still are not ready to accept the deal are being very careful. They are wondering if there are any other conditions to the offer. As it turns out, there is another condition to the deal. You may have to spend a couple of weekends doing a few "odd jobs" around your home or apartment. The jobs are not difficult, and most people can easily do the necessary work. There are no additional conditions.

Would you accept the deal now? If you answered "yes," you may skip the next several paragraphs and go directly to the section labeled, "How To Do It." If you did not answer "yes," continue reading.

People in this category are usually thinking about two things. First, some people have not yet realized that if they spend $500 early in the first year, they will get most ($400) of their money back by the end of that year. By the end of year two, they will have received another $400 bringing the total "gift" to $800. They have now spent $500, but they have received $800. They are $300 ahead! Then in each of the following years, they will continue to receive at least $400. This is a good deal.

Would you now be willing to accept such an offer? If you answered "yes," you may skip the next several paragraphs and go directly to the section labeled, "How To Do It." If you did not answer "yes," continue reading.

Some people are concerned because they do not have the $500 to spend during the first year. This is a very good reason to be concerned. There are at least three solutions to this problem. First, it is not necessary that all of the $500 be spent during the first year. Your investment could be spread out over several years. If you spread it over a five year period, you would need to spend $100 per year. If you spread it out over 10 years, you would only need to spend $50 per year. If you choose to spread your payments over a period of several years, you will still receive some of the $400 prize each year. But you will not begin to receive all $400 per year until you have invested $500.

For some people there is a second solution to not having the initial $500. You may be able to change your spending habits. This would allow you to use some of your money to make more money. In this example the initial $500 is equal to about the annual cost of one pack of cigarettes per day. In other words if you smoke one pack per day and quit, you now will have enough money to pay for your investment. (Remember, you only need this money in the first year. You would have the money to begin smoking again by the beginning of the second year.)

A third solution for not having the initial $500 would be to borrow the money. If you own some or all of your home, you could probably get a home improvement loan.

Are you now willing to accept the $400 per year offer? If you answered "yes," you should skip the next few paragraphs and go directly to the section labeled, "How To Do It." If you did not answer "yes," continue reading.

Only a few people get this far. Most have skipped to the the section labeled, "How To Do It." One of two things seems to be true. Either you are not yet convinced that the deal is good, or you will probably not benefit financially from the information in this lesson. If you are not yet convinced, that is okay. You should skip the next paragraph but read the rest of the lesson to get more information. You may change your mind after reading the lesson.

If you do not believe that you can benefit from the $400 per year offer, that is okay. You can read the lesson anyway. You will learn how thousands of people have saved hundreds of dollars each year. Maybe you will discover that it can be a good deal for you too.

How To Do It

You have probably guessed that the $400 deal mentioned above relates to energy-saving projects around your home or apartment. In addition the amount of money that you save could be much less or much more than $400 per year. Finally, the money that you must spend at the beginning could be a lot more or a lot less than $500. In other words, the exact numbers in the above example were just a sample. But the idea of spending some money to save even more money is generally correct.

The concept of energy conservation (savings) is easy. You use energy in your home for several things. For example, you use electrical energy to run your TV, to turn on your lights, to keep your refrigerator cool, *etc*. Some of this energy is wasted. If you can find a way to stop this waste, you can use less energy. This will save you money.

In Pennsylvania, heating a house or an apartment is usually the largest single use of energy. Hence, this would be a good place to begin to look for ways to save energy. The energy used to keep your living space warm can be measured by a unit called the BTU. (This stands for British Thermal Unit.) Table 23.1 shows the approximate number of BTU's that are contained in some common fuels.

Fuel	BTU's
1 ton of coal	25000000
1 kwh electricity	3413
1 Ft^3 natural gas	1031
1 barrel of oil	5800000
1 cord wood (maple)	21300000

Table 23.1 Energy of selected fuels

Important: From the information given in Table 23.1, it is impossible to know the cost of using a given fuel. The information in the table is just to give you an idea about the amount of energy in a given unit of fuel. It does not tell you anything about the cost of fuels.

To begin saving money you first must find the places in your home where energy is being wasted. There are many details related to energy savings in the home. This lesson cannot begin to cover all of them. A book on the topic is highly recommended. However, the following tips and estimates should be enough to get you started.

Water Heater

If you insulate the outside of your hot water tank, this will keep heat inside the tank and save you money. By adding 1 1/2 inches of insulation, heat loss could be cut by 400 kilowatt hours per year for electric tanks. At 5 cents per kilowatt hour, this would be about $20 per year. To save this $20 per year, it will cost you about $20 for the insulation. Hence, you get your money back within one year. Insulation on a gas hot water tank could save about 3,600 cubic feet of gas per year.

By turning down the thermostat on the hot water tank, you can save additional money. The amount that you save depends on how low you set the temperature. But the initial cost is zero. So any savings will be money in your pocket.

You can also save energy by adding insulation to the hot water pipes. They will hold the heat better. As a result, you will run less water waiting for the hot water to come out of the faucet.

Furnaces

One of the best ways to save money in this category is to have your furnace cleaned. This will improve its efficiency If you have an old furnace you may find that it would save you money to junk it. You could then replace your old, inefficient furnace with a newer model that is much more efficient. For example, many furnaces have an efficiency of less than 50%. Let us assume a 50% efficiency factor. If you modernize your heating system you can easily get an efficiency of 80%. This means that you will save $37.50 for every $100 worth of fuel that you buy. In other words, if your annual fuel bill is $800, you could save $300 each year.

Consider the installation of a timer on your heating system. It will turn your heat down each night and up again in the morning. Why overheat your house while you are warmly covered with blankets?

Fireplaces

Most fireplaces cost you energy. This is true whether you use them or not. In both cases warm air goes up the chimney. So, if you have a fireplace that you do not use, its opening should be sealed. This will prevent warm air from going up the chimney.

If you do use the fireplace, you should consider installing a glass front. This will allow you to see the fire, but help to keep heat from rushing from your room and going up the chimney.

Wood Burners

Most wood burning stoves will add heat to your home and save you money. But be careful about the installation. They can be dangerous (fire hazard) if not properly installed. Also, you will still have fuel costs unless you own lots of trees that you can cut down. And do not overlook the work associated with cutting, hauling, and spliting wood. Some people are not able to do this type of labor.

Insulation

Insulation is usually measured by its "R-value." The bigger the R-value, the better it can insulate. Different materials have different R-values. For example, 6 inches of rock wool has an R-value of 22. But 6 inches of fiber glass has an R-value of about 13 or 14.

There is no magic formula that tells you what the R-value should be. But some experts suggest R-values as high as R-38 in the attic. But R-19 values are also common. Window glass has an R-value less than 1. This means that heat moves very quickly through glass.

Insulation in your attic is an excellent way to cut down on heat loss. If you have less than 6 inches of insulation, you may be able to save money by adding more.

Several factors need to be considered before you insulate the walls of the house. But unless your heating bills are high, the payback period (the time that it takes to recover the money that you invested) may be quite long.

If you do the work yourself, you can probably recover the cost of insulating basement walls. You may want to consider insulating only the top part of the wall. The part that is above ground level is where most of the heat will escape.

Caulking and Weatherstriping

Because caulking is relatively cheap and you can easily do it yourself, the cost of caulking is almost always recovered. Check for cracks under the siding of frame houses. This is a good place to add caulking. Also, watch for cracked or missing putty around your windows. This is easily replaced.

If you feel drafts around windows and doors, it would save energy if you added weatherstriping.

Storm Windows

Storm windows, even if made from plastic, can help reduce heating costs. Windows have almost zero insulating quality.

Misc. Tips

Consider the use of an electric blanket. They cost only pennies per night. You can then turn down your thermostat and save many dollars.

Turn off lights and appliances when they are not in use. A penny saved is a penny earned.

Wear layers of clothing in the winter. If you do this when you are inside, you can then keep your house at a lower temperature and save energy costs.

Move your bed away from cold windows and outside walls.

Long underwear does help you to keep warm.

Alcohol and cigarettes lower, not raise, your body temperature. In other words, smoking and drinking makes you feel cooler during the winter.

Pants keep you warmer than skirts and dresses.

Use energy-saving light bulbs. Keep their wattage as low as possible.

Fluorescent lights use less energy than regular bulbs.

If you have difficult jobs to do, you may need to consult with a contractor for professional help.

A Little Bit More

There are many books and free pamphlets available that describe in detail how to cut your energy costs. Your utility company would be an excellent place to begin your search for current information. The school and public libraries would also be a good place to look for further information.

The following is a list of facts and figures relating to energy usage in America. Do not try to memorize the information in this list. It should be used to generate discussion and thought.

- √ The heat from burning one cord of oak wood is equal to the heat from one ton of coal.
- √ It takes 174 million pounds of paper to package food in one fast food chain for one year.
- √ A human being requires 341 BTU's of energy for one hour of normal activity.
- √ A frost-free refrigerator uses about three times more energy than a manual model.
- √ The energy used by 200 million Americans to cool buildings is about equal to the total energy used by 800 million Chinese citizens in one year.

Something to Try

In this activity you will calculate the cost of using selected electrical appliances. First, you must know how much one kilowatt hour (KWH) of electricity costs. You can determine this from your monthly bill. If not, call the electrical utility company and ask them how much 1 KWH costs.

Then select about a dozen appliances and write their names in column #1 of Table 23.3.

Next you must find the wattage for each of your selected appliances. This number is sometimes printed on the appliance. For example, you can usually see the wattage of a light bulb printed directly on the bulb. Sometimes the label does not indicate the wattage. But it may show the amperes or amps. The amperes are often abbreviated with an "A." To convert amps to watts, multiply the number of amps by 110. For example, if the label on the back of a TV shows 2 amps, you would multiply 110 by 2. This is 220 watts. Sometimes the watts and amps are both missing from the label of the appliance. When this happens you can estimate its wattage, look up the wattage in Table 23.2, check the information that came with the appliance, or call the manufacture. Write the wattage in column #2.

Kilowatts are listed in Column #3 . This is just column #2 multiplied by 1,000. (Move the decimal point 3 places to the right. Add zeros if you need to.)

In column #4 you should list the number of hours that you use the appliance. If you use the appliance for less than one hour, use a decimal number to show part of an hour. For example, if you use an appliance for 15 minutes, this would be 25% of one hour. As a decimal, this number is .25. (To change a percent to a decimal, move the decimal point two places to the left and take away the percent sign.)

Column #5 is the total energy used. This comes by multiplying the kilowatts in column #3 by the hours in column #4.

Column #6 is your total cost for that appliance for the number of hours that you listed in column #4.

Lesson 23 Continued

Appliance	Watts (Amps X 110)	Kilowatts (Watts X 1000)	Hours Used	Total Energy (Hours X Kilowatts)	Total Cost (Energy X Cost)

Table 23.3 Daily cost of selected appliances

To determine how much it costs to run all of the applicances, add the numbers in column #6.

Example:

Let us say that your electricity cost 5 cents ($0.05) per KWH. We would write this as .05. If we want to find the cost of using a desk fan for 11 hours, we would write "desk fan" in column #1. We would place the 11 in column #4. We look at the label on the fan and find that it uses 70 watts of power. We write 70 in column #2. To calculate the kilowatts we divide 70 by 1000. This is .07. We write this answer in column #3. The total energy (column #5) would be 11 hours times .07 kilowatts. This is .77 kilowatt hours. We write .77 in column #5. Finally, to calculate the total cost we multiply our electrical rate of .05 (5 cents per KWH) times the total energy of .77. This is .0385 cents. This can be rewritten as $0.0385. To round this number off it would become $0.04. In other words, 4 cents is the cost of running that fan for 11 hours.

Appliance	Average Wattage
Bottle Warmer	400
Clothes Dryer	1325
Clock	2
Coffemaker (auto)	830
Dehumidifier	525
Dishwasher (no heater)	290
Dishwasher (heater)	1155
Fan (attic)	370
Fan (desk)	70
Fan (furnace)	225
Hair Dryer	235
Heater, radiant	1095
Hot Plate	1140
Iron	1000
Radio	90
Range (total)	12500
Refrigerator	205
Sewing Machine	75
Shaver	15
TV	220
Toaster	1000
Vacuum Cleaner	375
Waffle Iron	855
Washer	289
Water Heater (66 Gal)	3250
Water Pump	265

Table 23.2 Wattages for selected appliances

Physical Science: Lesson 24

Kitchen Chemistry

Teacher's Page

Lesson Objectives: This lesson should:

- √ develop the concept of chemistry as a common part of our everyday life.
- √ emphasize how a knowledge of some basic chemistry can be useful around the house.
- √ explain why water does not always boil at the same temperature.

For Class Discussion:

- √ Why is it very difficult to get wet wood to burn?

For More Information:

C. Heimler, *Principles of Science, Book Two*, Charles E. Merrill, Columbus, OH, 1979. (pages 333-359)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 263-298)

Physical Science: Lesson 24

Kitchen Chemistry

Science Concepts:

Fire
Bleach
Boiling Point

The housewife or househusband frequently encounters chemistry in her or his daily routine. A good knowledge of science can help us do our work with less effort. The problem is that we do not always understand the science concept behind our activities. This lesson will consider several chemistry topics that could help us do houshold tasks more effectively or more safely.

In this lesson all of the temperatures will be listed in degrees Celcius (C). If you want to learn how to convert them to degrees Fahrenheit (F), see the "Beyond the Basics" section of this lesson.

Boiling:

Evaporation is the changing of a liquid into a gas. A drop of water on the floor will evaporate. This process requires energy in the form of heat. If we add a lot of heat energy to water, it will evaporate very rapidly. When bubbles form and rise to the surface and "explode," we call that process boiling. It is nothing more than very rapid evaporation.

The temperature at which boiling occurs is called the boiling point. Different liquids have different boiling points. For example, water boils at 100 degrees C. Iron will not boil until its temperature reaches 3,000 degrees C. Other substances boil at very cold temperatures. For example, oxygen will boil when its temperature reaches -184 degrees C. This is quite cold. In fact, all of the substances that we commonly think of as gases will boil at very low temperatures. Otherwise, they would be liquids at room temperature. (Table 24.1 lists the boiling point of several substances.)

Substance	Boiling Point
Aluminum	2467
Chlorine	-34
Copper	2595
Hydrogen	-252
Mercury	357
Water	100

Table 24.1 Boiling points, degrees Celcius

It is important to realize that once something begins to boil, it will not get any hotter. It may boil faster, but not hotter. You can save energy (gas or electric) by keeping the heat under a pan of boiling water as low as possible. Water that is just barely boiling will cook your egg as fast as water that is boiling very rapidly.

You may have heard stories about campers in the mountains being unable to make a hardboiled egg. Boiling an egg on Pikes Peak (14,000 feet elevation) is not as easy as you would think. If you cook an egg at 14,000 feet for 3 minutes, it will not be hardboiled like an egg that was cooked for 3 minutes at sea level. Why not?

The reason is that the boiling point of water is changed by the air pressure. The lower the air pressure, the lower the boiling point. At 14,000 feet the air pressure is much less than at sea level. Hence, water at 14,000 feet will boil at a lower temperature than water at sea level. At 14,000 feet of elevation, water will boil at a temperature of only 86 degrees C. Since this temperature is much lower than normal, the egg does not cook very well. Will adding heat to the boiling water make the egg cook faster? Absolutely not. Remember, the temperature of boiling water does not increase when heat is added.

You may wonder if the air pressure can change enough to effect the boiling point of water. It can, and the following facts will show how much the weight (pressure) of air can change. At sea level a cubic mile of air weighs about 5,600,000 tons. At an elevation of 220 miles, it weights only two ounces.

Could we quickly cook an egg at 14,000 feet? Yes, but we would have to use a pressure cooker. A pressure cooker is a special pot with a top that seals itself to the bottom of the cooker. When heat is applied, the pressure in the cooker increases. (There is a safety valve that prevents the pressure from getting too high and blowing up the cooker.) With an increase in pressure, there is an increase in the boiling point of water. This allows the temperature of the water to be hotter than normal. The egg will cook more quickly at this higher temperature.

Pressure cookers are frequently used when you do home canning. The pressure allows the water to go above 100 degrees Celcius. The food is quickly blanched, and the germs are more easily killed at these higher temperatures.

Fire:

Fire is a very common chemical reaction. If you have a gas stove or a gas hot water heater, you probably have a fire in your house every day. Furnaces that burn coal, oil or gas can also create a fire in your house. Some people build fires in wood stoves or fire places to help heat their home. On Valentine's Day and other special days, some people have a candle-light dinner. All of the above are examples of fire in a home. They all have at least two things in common. First, each of the above fires is easy to start. Second, each of the above fires is controlled.

Prior to the 1800s, there was no easy way to start a fire. If you wanted to start a new fire, you would usually get some hot coals from a neighbor. Or, you could strike a hard rock called flint against a softer rock called pyrite. This would make a spark that could begin a fire. In those days there was no such thing as a pilot light. There were no matches.

There were no matches because no one understood the chemical reactions in a fire. It was a French scientist, Lavoisier, who finally solved the mystery of fire. He said that fire was a reaction between a combustible material and an active part of the air. He called the active part of the air "oxygen."

It was later realized that the combustible material must reach a certain temperature before it would interact with oxygen and burn. With this clue, scientists began to look for a material that would burn at a low temperature. They discovered phosphorus sulfide. They put phosphorus sulfide on a small stick. Then when the stick was rubbed on a rough surface, the friction would heat the chemical. It would begin to burn. And that is how matches were invented.

We soon learned that things other than wood could be used as a combustible substance. Coal and oil were used by many people as fuels during the 19th and 20th centuries. Natural gas and gasoline are also popular fuels.

As the use of fuels became more popular in homes and businesses, the risk of accidental fire became more of a concern. In the early days, about the only way to fight a fire was to pour water on it. Although this worked on some fires, no one knew why. We now know that the cool water lowers the temperature of the fuel; this puts out the fire.

But water does not work well for putting out some fires. For example, water only spreads an oil or grease fire. Furthermore, water does not work well on an electrical fire. Prior to the mid-1900s, it was clear that we needed better ways to put out fires.

Because of an understanding of chemistry, scientists have developed many different forms of fire extinguishers. Some fire extinguishers work better on electrical fires. Others work better on oil and grease fires. Some of these newer extinguishers do not reduce the temperature of the fuel. Instead, they push away the oxygen. Without oxygen, there can be no fire.

Some people keep a box of baking soda near their stove. If a pan of grease were to catch on fire, they would pour the baking soda on the grease. This action tends to smoother the fire without splashing the grease. You may want to consider placing a box of baking soda near your stove. (Of course, you should also have one or more commercial fire extinguishers available in case you need them.)

Bleaching:

The concept of bleaching is very common around the laundry room. You can use a bleach to remove certain stains and to make white clothes whiter.

Dangerous Mixing:

Sometimes two chemicals can interact with each other and become dangerous. This can be true even when the two chemicals are relatively safe when used alone. For example, ammonia and chlorine make a deadly combination.

It is not hard to *accidently* mix these two chemicals. Many cleaning solutions contain ammonia. Some bleaches contain a liquid form of chlorine. It is easy to imagine that a person could use an ammonia-based cleaner to clean a sink. If the sink still had a stain, one might add a chlorine-based bleach to remove the stain. The chlorine bleach would now be in direct contact with the ammonia. A poisonous gas, chlorine, is the result.

Beyond the Basics

There are several temperature scales that all do the same thing. They measure the amount of heat that is present. You are probably most familiar with the Fahrenheit scale. Most countries and most scientists use the Celcius scale to measure temperature. You can convert from one scale to the other. Here is one method that works.

From Fahrenheit to Celcius:

1) Add 40 to the Fahrenheit temperature
2) Multiply by 5
3) Divide by 9
4) Subtract 40 to get Celcius degrees

From Celcius to Fahrenheit:

1) Add 40 to the Celcius temperature
2) Multiply by 9
3) Divide by 5
4) Subtract 40 to get Fahrenheit degrees

For example, convert 98.6 degrees Fahrenheit to degrees Celcius.

Step 1: Add 40 to Fahrenheit degrees
$40 + 98.6 = 138.6$

Step 2: Multiply by 5
$138.6 \times 5 = 693$

Step 3: Divide by 9
$693 \div 9 = 77$

Step 4: Subtract 40
$77 - 40 = 37$ degrees Celcius

Something to Try

Light a small birthday candle. Place it in a small candle holder on the table. Put a drinking glass upsidedown over the candle. Watch as the candle slowly goes out. Why did the candle go out?

The flame used up the oxygen. When the oxygen was gone from the air, the fire went out. Some fire extinguishers work on this principle.

Physical Science: Lesson 25

Are You Cool?

Teacher's Page

Lesson Objectives: This lesson should:

√ develop the concept of evaporation.

√ emphasize the importance of evaporation in keeping people's temperature from going too high.

√ explain why some liquids feel cooler than others when placed on your skin.

For Class Discussion:

√ Would spraying water on the roof of a trailer help to keep it cool?

For More Information:

C. Heimler, *Principles of Science, Book One*, Charles E. Merrill, Columbus, OH, 1979. (pages 210-213)

J. M. Pasachoff *et. al.*, *Physical Science*: (Teacher's Edition), Scott, Foresman and Co., Glenview, IL, 1983. (page 164-168)

Physical Science: Lesson 25

Are You Cool?

Science Concept:

Evaporation

Did you ever feel cool after stepping out of a nice hot shower? Shouldn't you feel warm, not cool? The room is warm. You were not cool before you took a shower. Why do you feel cool now?

Did you ever feel a cool spot when a nurse or doctor put alcohol on your arm just before giving you a shot? Was the alcohol in the refrigerator? Probably not. Rubbing alcohol is usually stored at room temperature. Why did that liquid feel cool to your arm?

Did you ever feel cool after a swim? Sometimes people feel warmer in the water than they do in the air. This can be true even when the air is *warmer* than the water! Why is this true?

What do all of the above situations have in common? Evaporation. Yes, evaporation is sometimes the answer to why people feel cool. What is evaporation? How can it make us feel cool? Evaporation is the process of a liquid turning into a gas. This process requires energy. The energy can be in the form of heat from our body. That is why we feel cool when a liquid on our body evaporates.

The faster a liquid evaporates, the more heat it takes from your skin. Alcohol evaporates faster than water. That is why alcohol on your skin can make you feel cooler than water on your skin. If you spill gasoline on your skin (you should not do this), it will evaporate very rapidly. Your skin will feel cool.

Now that you know this information, can you think of a way to feel warmer after getting out of a shower? One way would be to dry yourself as quickly as possible. Then there would be no water on your body to evaporate. This would allow you to feel warmer.

The towel now has all of the water that was on your body. Will it get cooler as the water evaporates? Yes. The towel will give up some of its heat to the water as evaporation takes place. But the towel cannot make its own heat. It gets its heat from the air that is in the room. So a towel will probably dry more slowly than your skin.

A Little Bit More

Can you think of a way that your body uses evaporation to keep you feeling better? Clue: It has to do with keeping cool in the summer. The answer is sweating! We often think of the "correct" body temperature as 98.6 degrees. Your body temperature must not change by more than a few degrees or problems can result. When you are working or exercising your body temperature will begin to go up. If it begins to get too high, you will sweat. Your sweat will evaporate and take heat from your body. You will feel a little cooler.

Dogs do not sweat. They have no sweat glands. How do they stay cool in hot weather? They pant. Panting allows saliva (water) to evaporate from their tongue. This helps to keep dogs cool. You should not try to prevent a dog from panting. If you do, it could cause an overheating problem for the dog.

Something to Try

Find a thermometer that will not be damaged by liquid. Place a jar of water in the room. Place a small amount of rubbing alcohol in another jar. Wait for both liquids to reach room temperature. This could take an hour or more. Place a thermometer in the container of water. Wait a minute or two and read the temperature. Be sure to read the temperature with the thermometer still in the liquid. Now put the thermometer in the rubbing alcohol. Again wait a minute or two, and read the temperature. You should find that the two temperatures are equal. If not, the liquids may not yet be at room temperature. Or, maybe you pulled the thermometer out of the liquid before you read it.

You now know that the liquids are the same temperature. Place a few drops of the water on your skin. Notice if that spot feels warm or cool. Now place a few drops of the alcohol on your skin. Notice if that spot feels warm or cool.

Did you notice a difference in the temperature of the two spots? If all went well, you may have noticed that the alcohol spot felt cooler. That is because it evaporated faster. The alcohol took heat from your skin faster than the water took heat from your skin.